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(12) **United States Patent**
Medasani et al.

(10) **Patent No.: US 9,086,484 B2**
(45) **Date of Patent: Jul. 21, 2015**

(54) **CONTEXT-BASED TARGET RECOGNITION**

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(73) Assignee: **The Boeing Company**, Chicago, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 215 days.

(21) Appl. No.: **13/173,891**

(22) Filed: **Jun. 30, 2011**

(65) **Prior Publication Data**

US 2013/0004017 A1 Jan. 3, 2013

(51) **Int. Cl.**

G06K 9/00	(2006.01)
G01S 13/90	(2006.01)
G01S 7/41	(2006.01)
G06K 9/46	(2006.01)
G06K 9/48	(2006.01)
G06K 9/72	(2006.01)

(52) **U.S. Cl.**

CPC ***G01S 13/9035*** (2013.01); ***G01S 7/412*** (2013.01); ***G06K 9/4604*** (2013.01); ***G06K 9/48*** (2013.01); ***G06K 9/72*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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Assistant Examiner — Sean Conner
(74) *Attorney, Agent, or Firm* — Yee & Associates, P.C.

(57) **ABSTRACT**

A method and apparatus for identifying a target object. A group of objects is identified in an image. The group of objects provides a context for identifying the target object in the image. The target object is searched for in the image using the context provided by the group of objects.

13 Claims, 19 Drawing Sheets

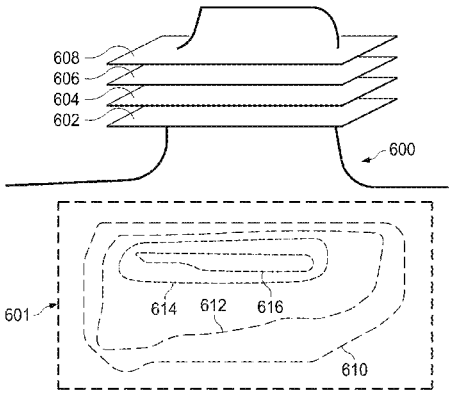

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FIG. 1

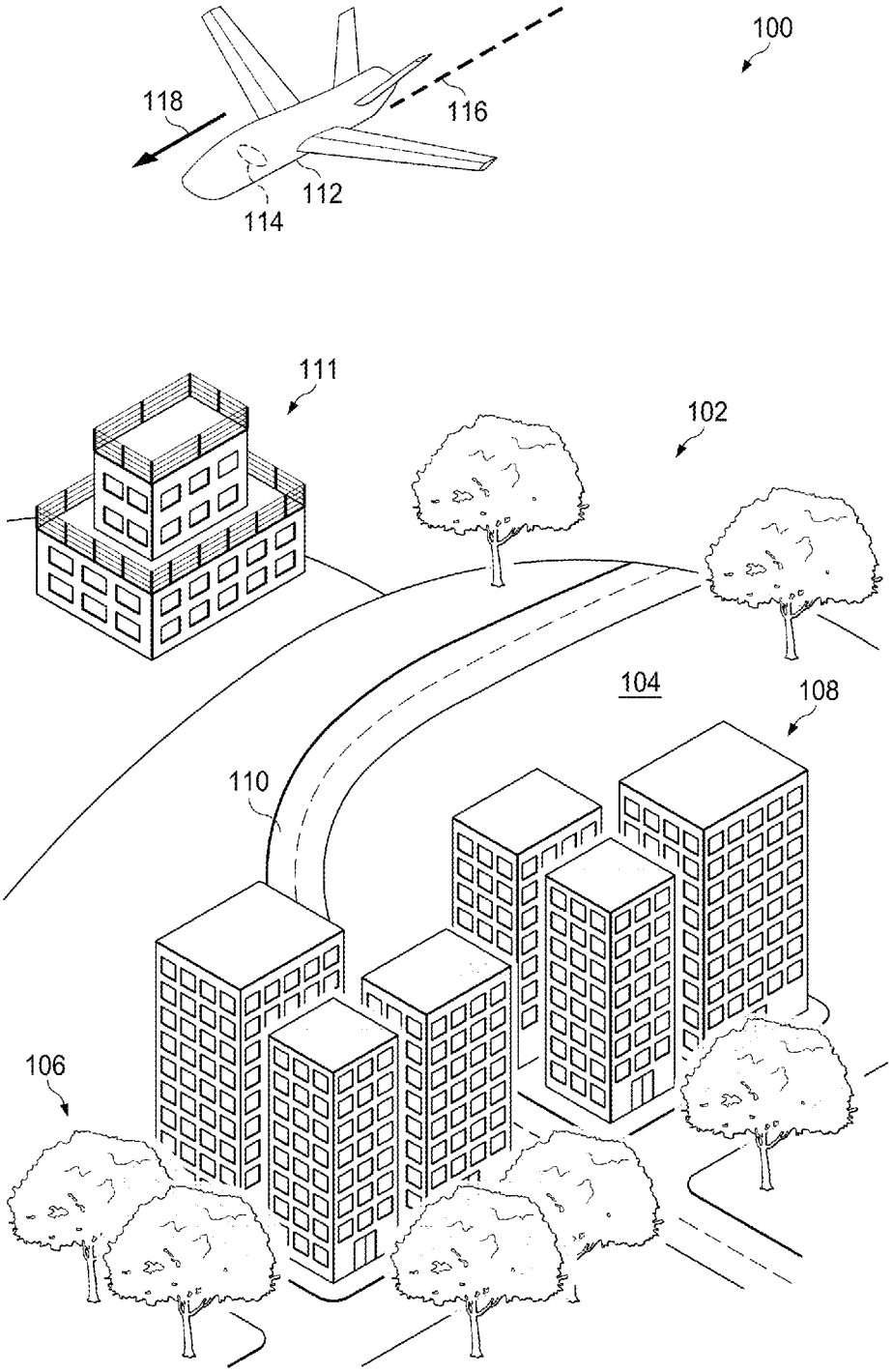


FIG. 2

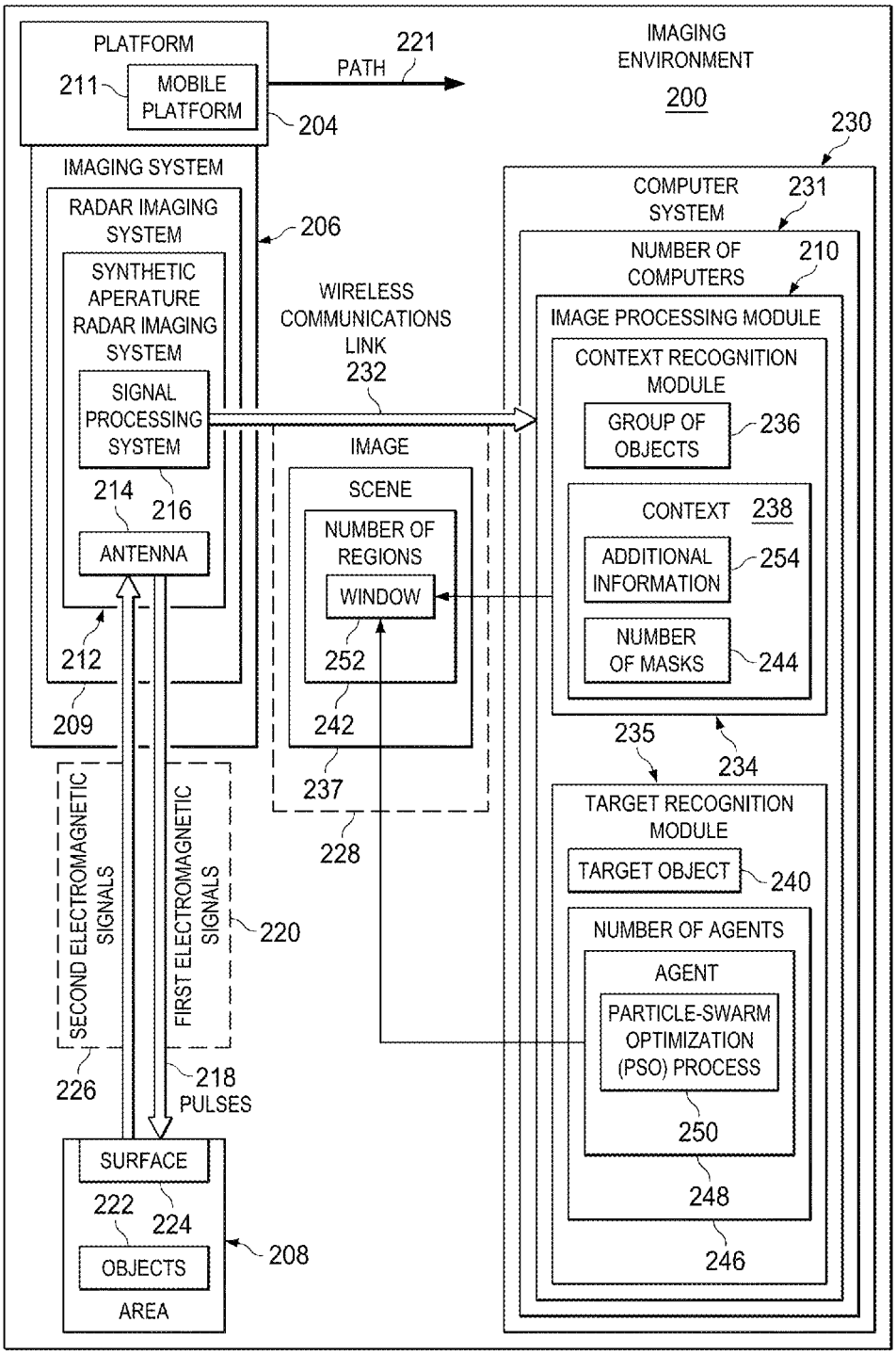

PLATFORM
211
MOBILE PLATFORM
204
221
PATH
IMAGING ENVIRONMENT
200
230
IMAGING SYSTEM
RADAR IMAGING SYSTEM
206
SYNTHETIC APERATURE RADAR IMAGING SYSTEM
SIGNAL PROCESSING SYSTEM
214
216
ANTENNA
212
209
WIRELESS COMMUNICATIONS LINK
232
COMPUTER SYSTEM
231
NUMBER OF COMPUTERS
210
IMAGE PROCESSING MODULE
CONTEXT RECOGNITION MODULE
GROUP OF OBJECTS
236
CONTEXT
238
ADDITIONAL INFORMATION
254
NUMBER OF MASKS
244
IMAGE
SCENE
NUMBER OF REGIONS
WINDOW
252
242
237
228
235
234
TARGET RECOGNITION MODULE
TARGET OBJECT
240
NUMBER OF AGENTS
AGENT
PARTICLE-SWARM OPTIMIZATION (PSO) PROCESS
250
248
246
SECOND ELECTROMAGNETIC SIGNALS
FIRST ELECTROMAGNETIC SIGNALS
220
226
218
PULSES
SURFACE
222
224
OBJECTS
208
AREA

FIG. 3

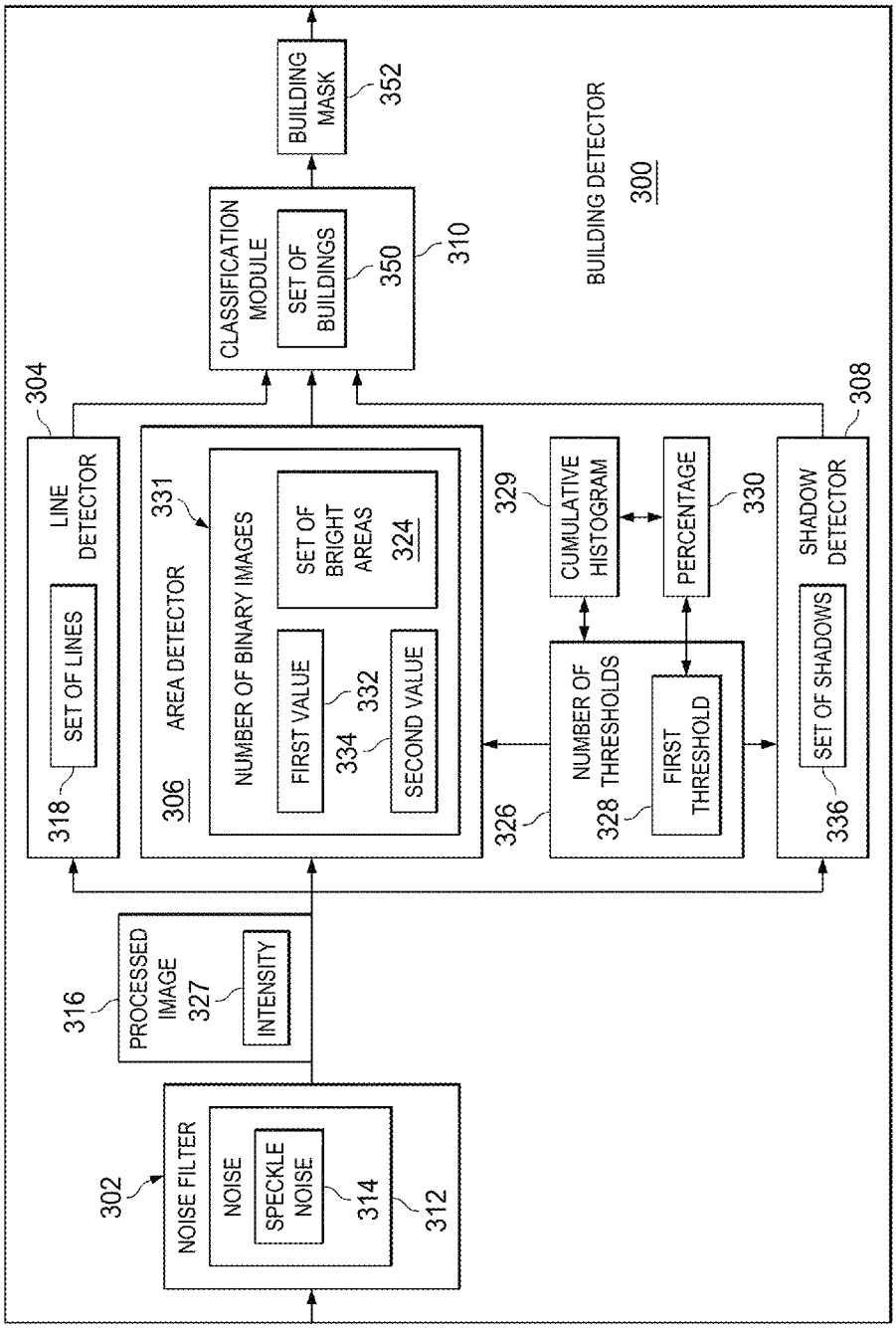

BUILDING DETECTOR
300
NOISE FILTER
302
NOISE
SPECKLE NOISE
314
312
PROCESSED IMAGE
316
327
INTENSITY
LINE DETECTOR
304
SET OF LINES
318
AREA DETECTOR
306
331
NUMBER OF BINARY IMAGES
FIRST VALUE
334
332
SECOND VALUE
SET OF BRIGHT AREAS
324
329
CUMULATIVE HISTOGRAM
PERCENTAGE
330
NUMBER OF THRESHOLDS
328
FIRST THRESHOLD
326
SHADOW DETECTOR
308
SET OF SHADOWS
336
CLASSIFICATION MODULE
SET OF BUILDINGS
350
310
BUILDING MASK
352

FIG. 4

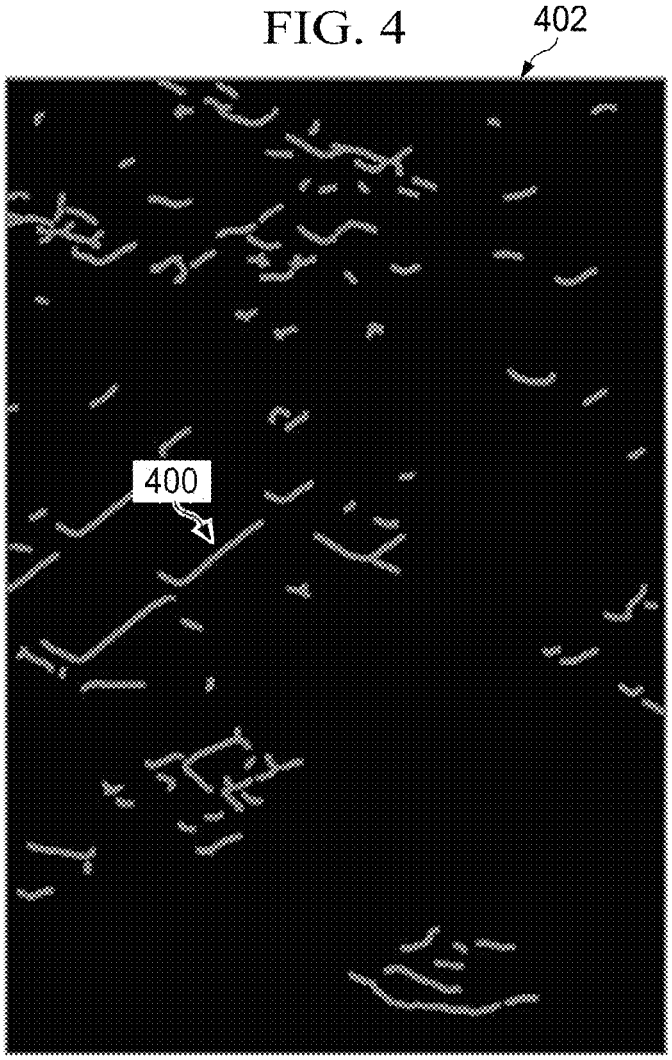


FIG. 5

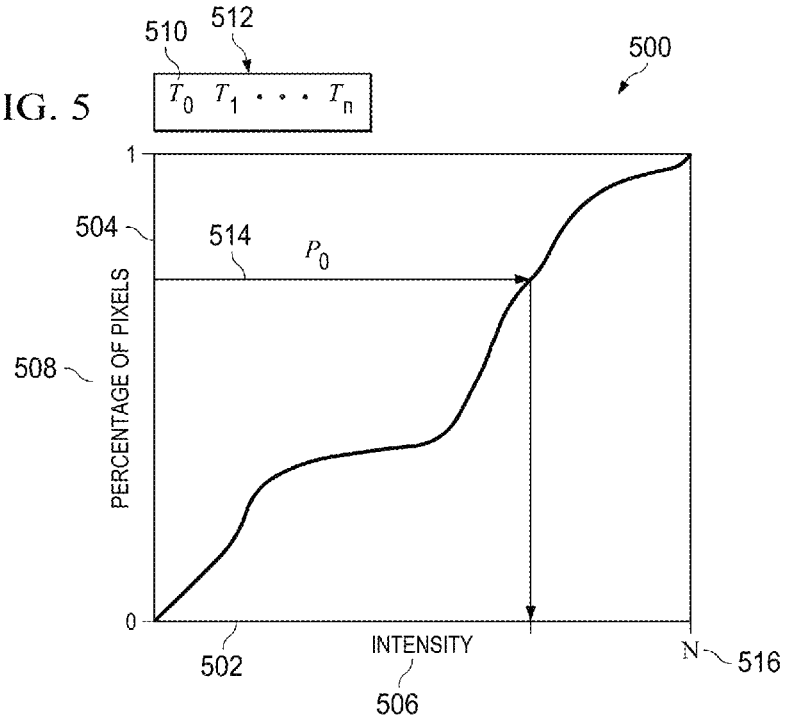
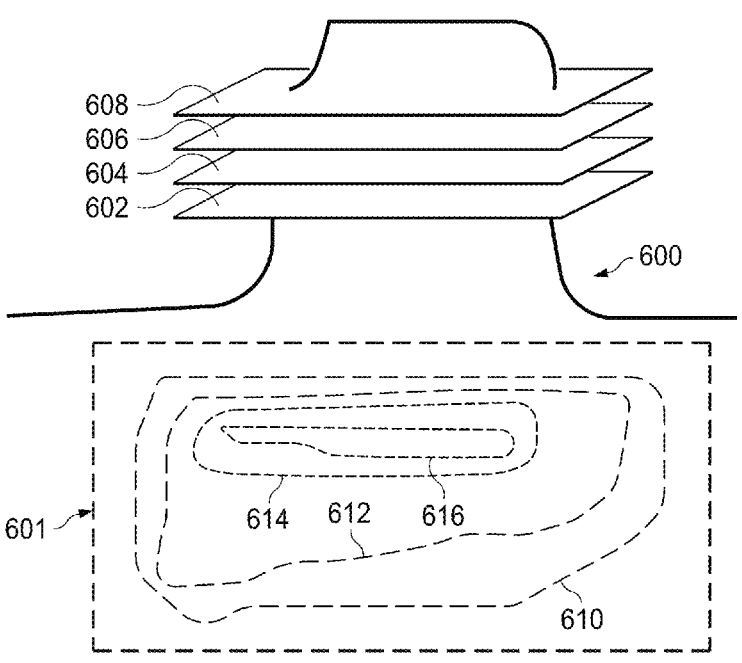

510
512
500
T_0 T_1 • • • T_n
1
504
514
P_0
508
PERCENTAGE OF PIXELS
0
502
INTENSITY
506
N
516

FIG. 6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606
604
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600
601
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612
616
610

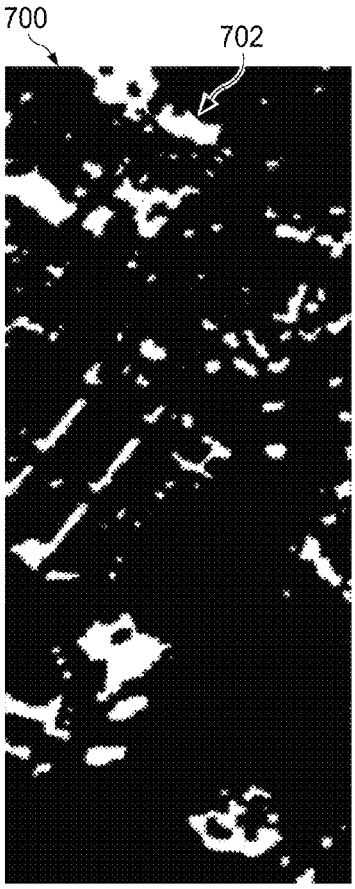


FIG. 7

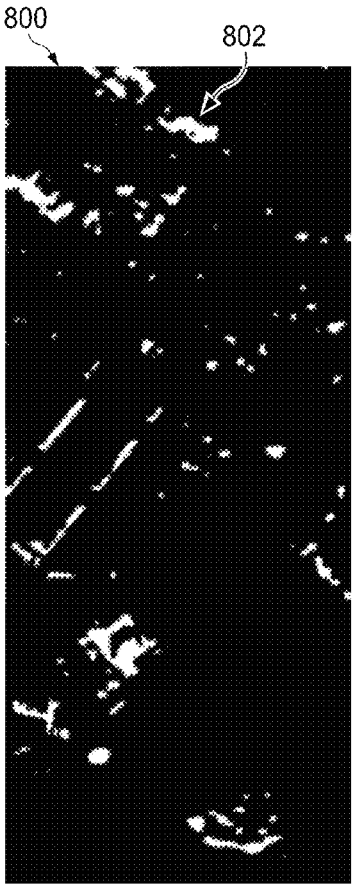


FIG. 8

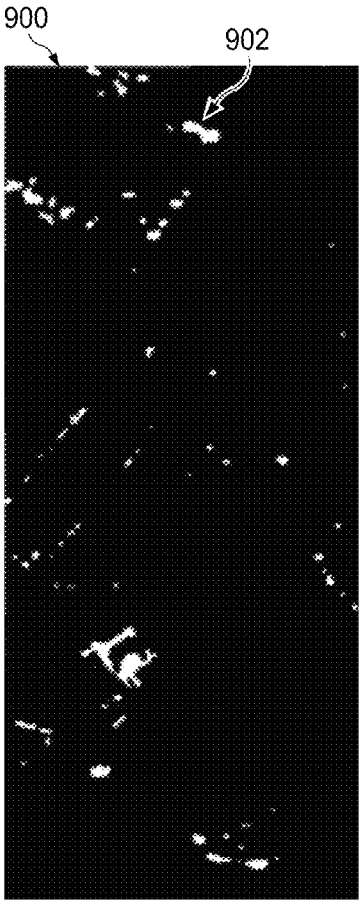


FIG. 9

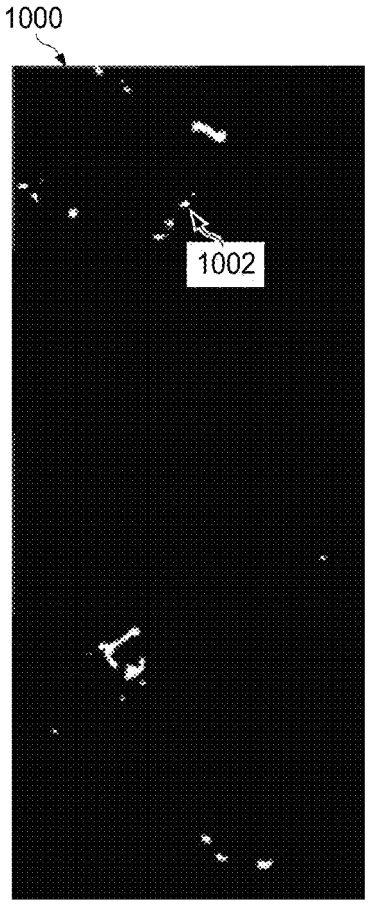


FIG. 10

FIG. 11

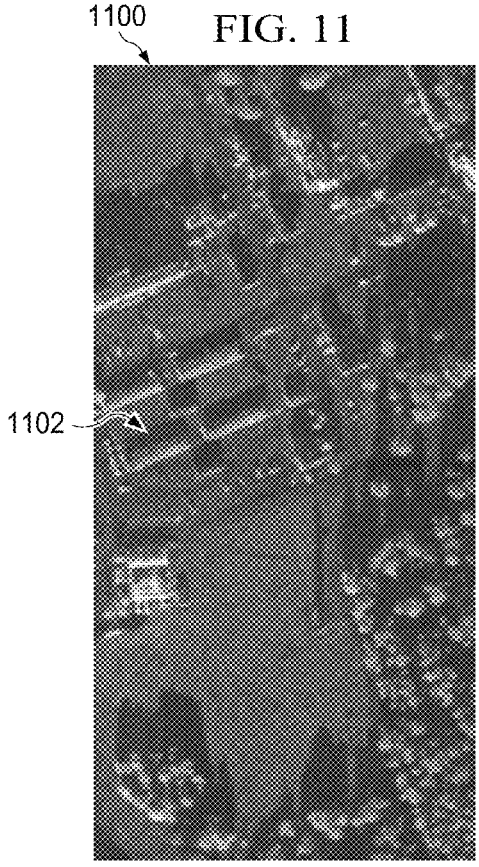
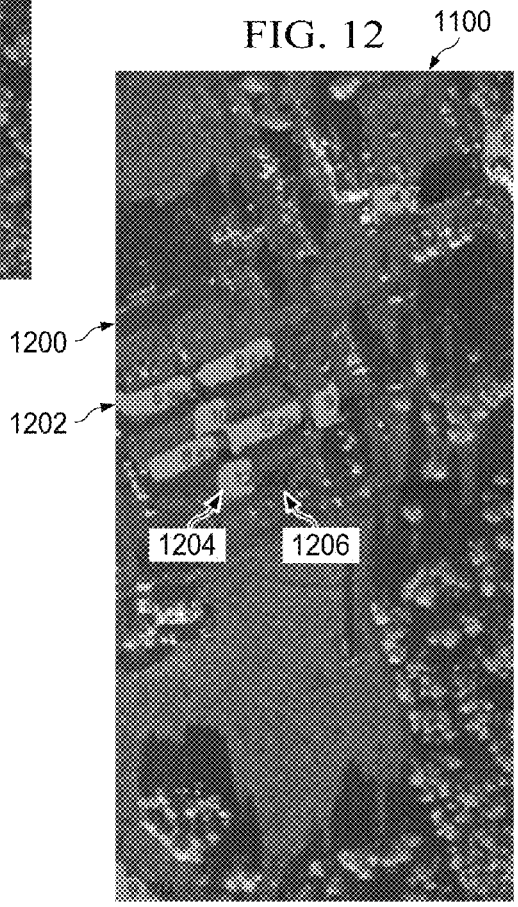


FIG. 12



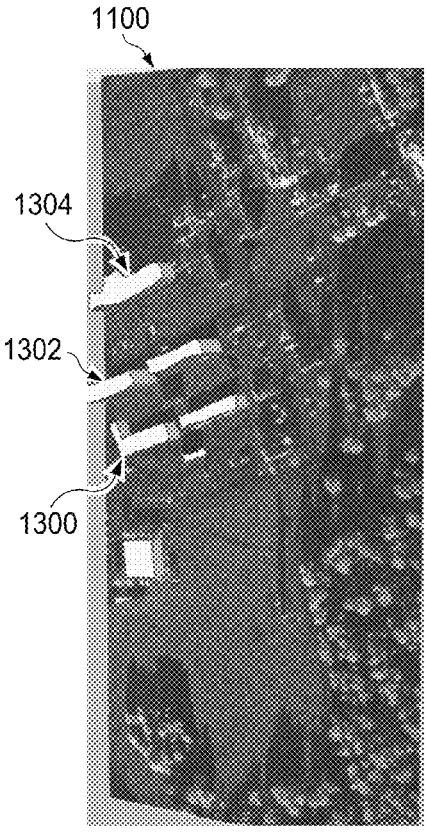
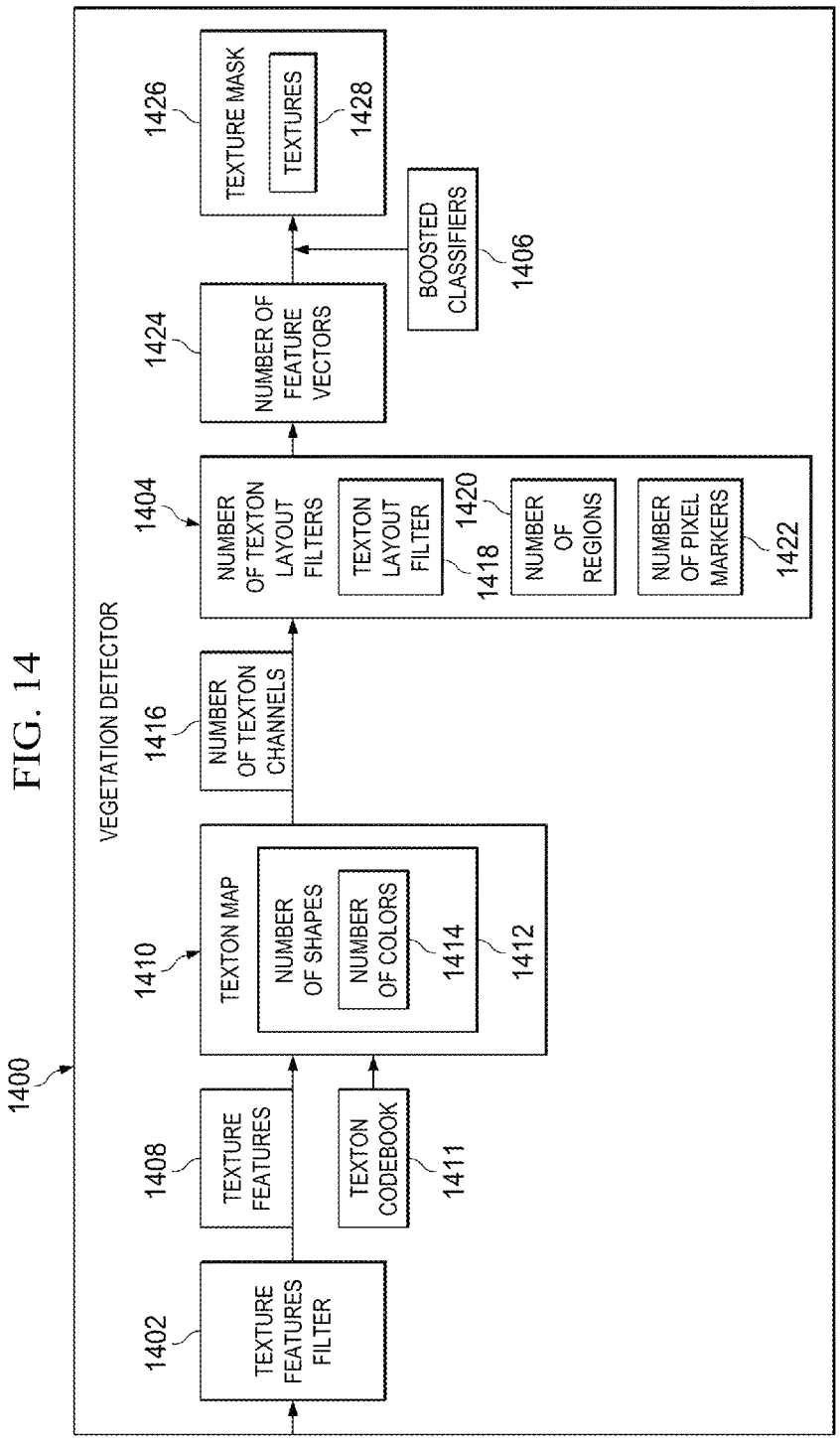


FIG. 13

FIG. 16

FIG. 14


1400
VEGETATION DETECTOR
1402
TEXTURE FEATURES FILTER
1408
TEXTURE FEATURES
1411
TEXTON CODEBOOK
1410
TEXTON MAP
NUMBER OF SHAPES
NUMBER OF COLORS
1414
1412
1416
NUMBER OF TEXTON CHANNELS
1404
NUMBER OF TEXTON LAYOUT FILTERS
TEXTON LAYOUT FILTER
1418
1420
NUMBER OF REGIONS
NUMBER OF PIXEL MARKERS
1422
1424
NUMBER OF FEATURE VECTORS
BOOSTED CLASSIFIERS
1406
1426
TEXTURE MASK
TEXTURES
1428

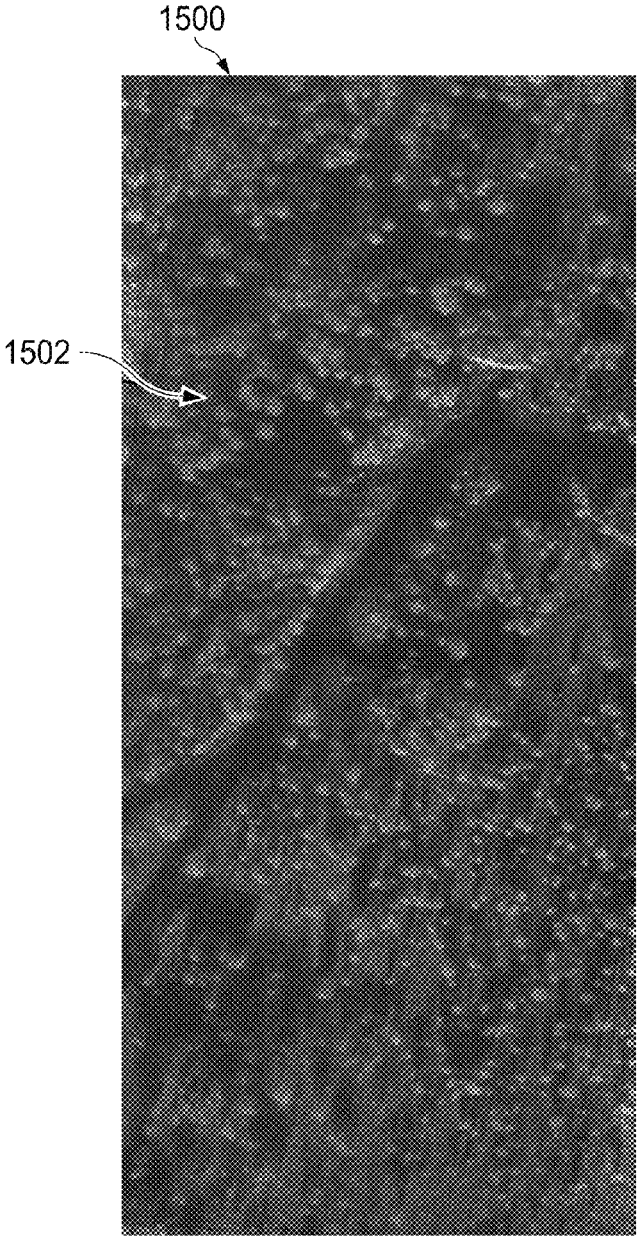
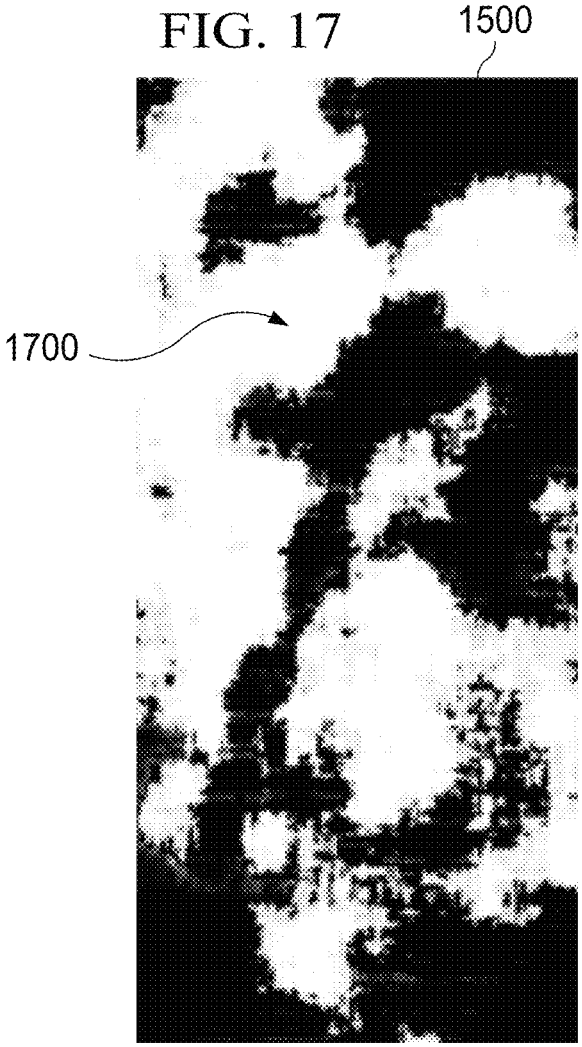


FIG. 15

FIG. 17



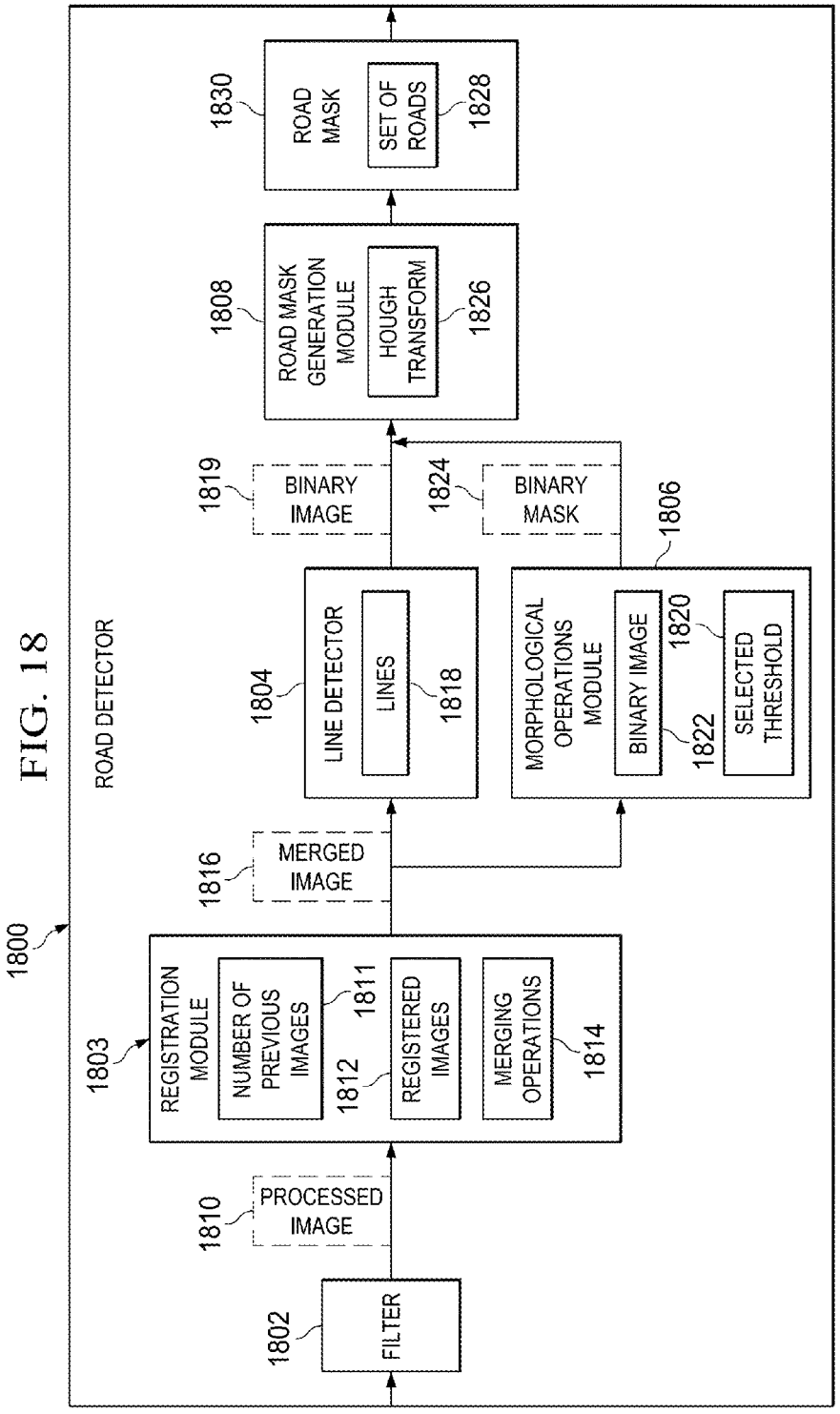

1800
ROAD DETECTOR
1802
FILTER
1810
PROCESSED IMAGE
1803
REGISTRATION MODULE
NUMBER OF PREVIOUS IMAGES
1811
1812
REGISTERED IMAGES
MERGING OPERATIONS
1814
1816
MERGED IMAGE
1804
LINE DETECTOR
LINES
1818
1806
MORPHOLOGICAL OPERATIONS MODULE
BINARY IMAGE
1820
1822
SELECTED THRESHOLD
1819
BINARY IMAGE
1824
BINARY MASK
1808
ROAD MASK GENERATION MODULE
HOUGH TRANSFORM
1826
1830
ROAD MASK
SET OF ROADS
1828

FIG. 18

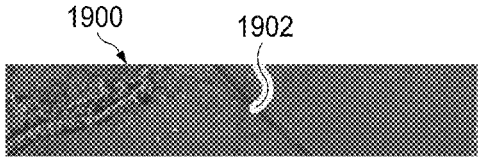


FIG. 19

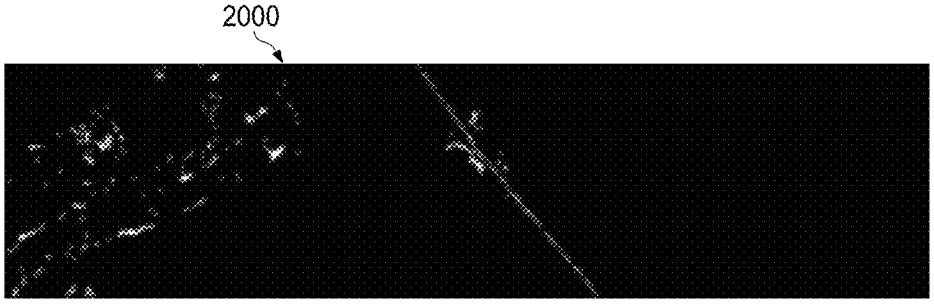


FIG. 20

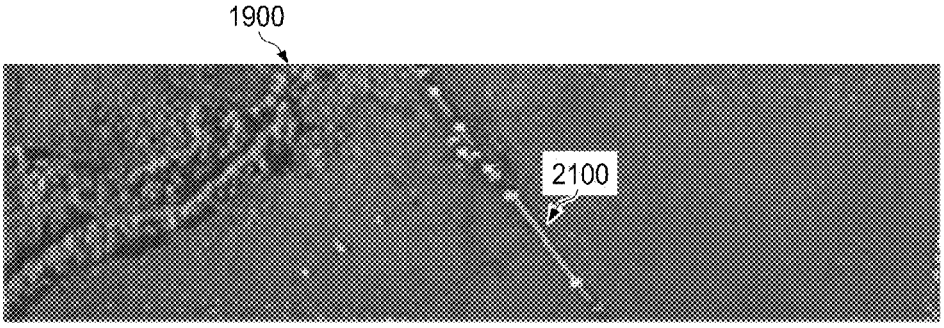


FIG. 21

FIG. 22

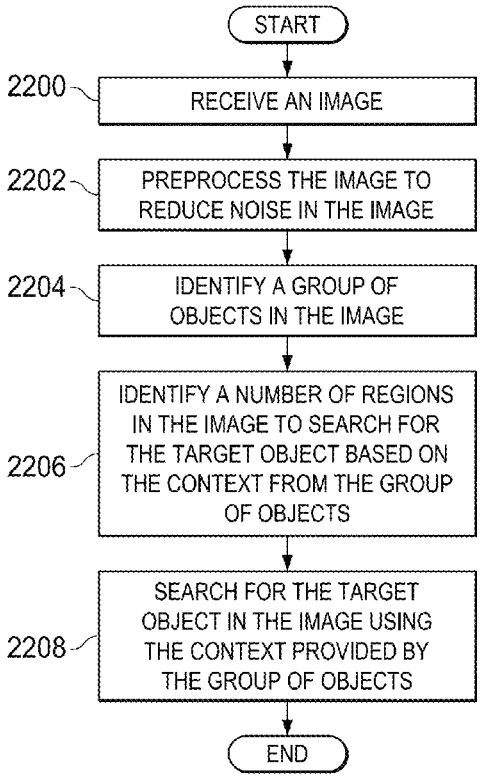
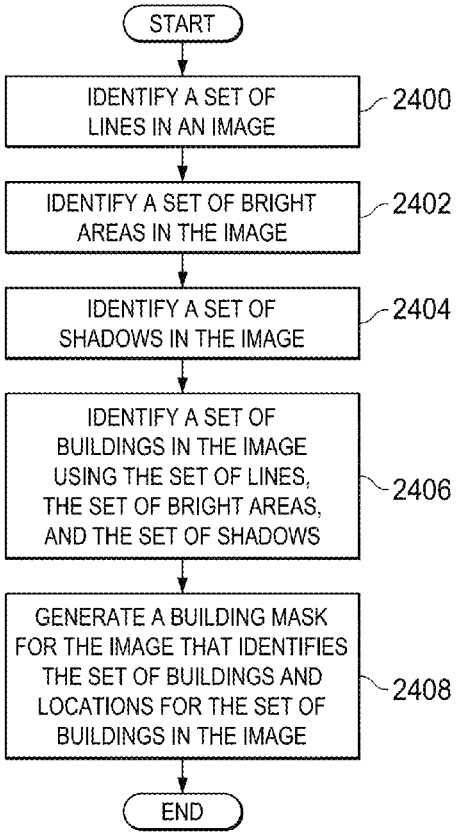

START
2200
RECEIVE AN IMAGE
2202
PREPROCESS THE IMAGE TO REDUCE NOISE IN THE IMAGE
2204
IDENTIFY A GROUP OF OBJECTS IN THE IMAGE
2206
IDENTIFY A NUMBER OF REGIONS IN THE IMAGE TO SEARCH FOR THE TARGET OBJECT BASED ON THE CONTEXT FROM THE GROUP OF OBJECTS
2208
SEARCH FOR THE TARGET OBJECT IN THE IMAGE USING THE CONTEXT PROVIDED BY THE GROUP OF OBJECTS
END

FIG. 24


START
IDENTIFY A SET OF LINES IN AN IMAGE
2400
IDENTIFY A SET OF BRIGHT AREAS IN THE IMAGE
2402
IDENTIFY A SET OF SHADOWS IN THE IMAGE
2404
IDENTIFY A SET OF BUILDINGS IN THE IMAGE USING THE SET OF LINES, THE SET OF BRIGHT AREAS, AND THE SET OF SHADOWS
2406
GENERATE A BUILDING MASK FOR THE IMAGE THAT IDENTIFIES THE SET OF BUILDINGS AND LOCATIONS FOR THE SET OF BUILDINGS IN THE IMAGE
2408
END

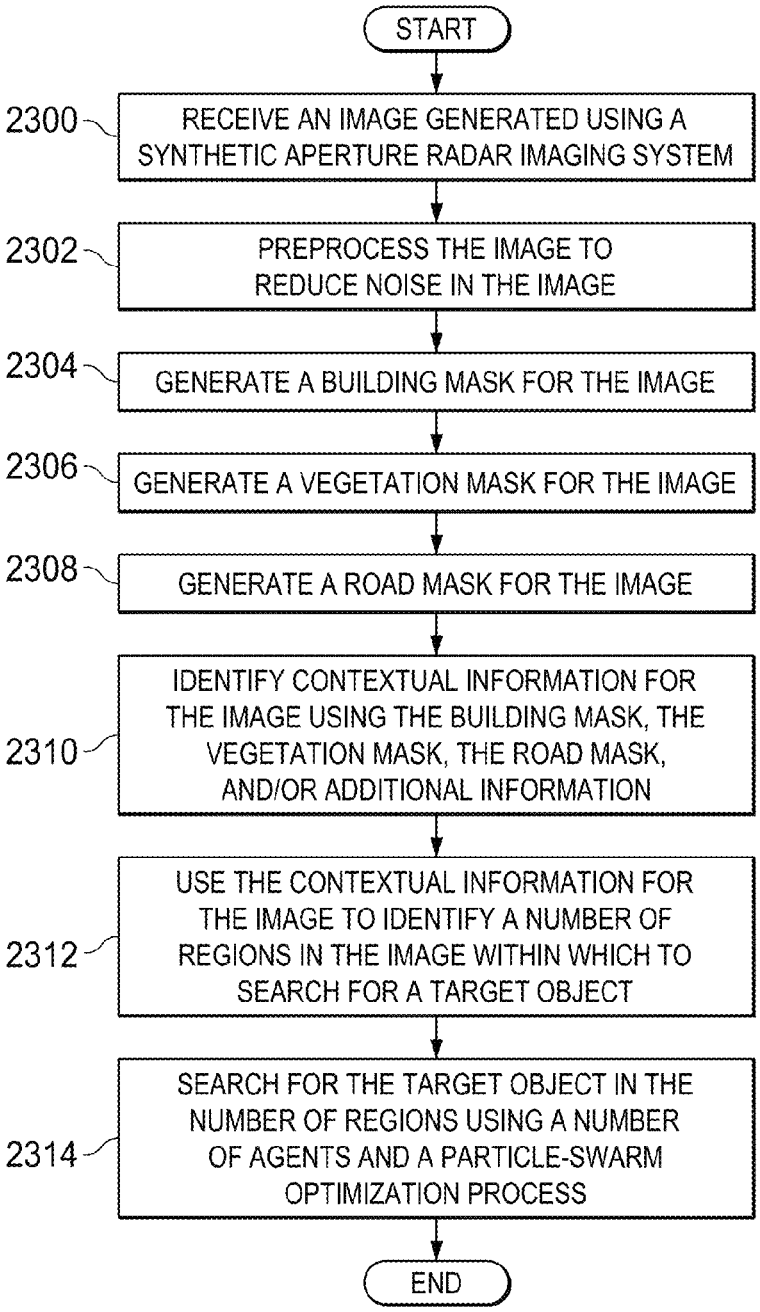

START
2300
RECEIVE AN IMAGE GENERATED USING A SYNTHETIC APERTURE RADAR IMAGING SYSTEM
2302
PREPROCESS THE IMAGE TO REDUCE NOISE IN THE IMAGE
2304
GENERATE A BUILDING MASK FOR THE IMAGE
2306
GENERATE A VEGETATION MASK FOR THE IMAGE
2308
GENERATE A ROAD MASK FOR THE IMAGE
2310
IDENTIFY CONTEXTUAL INFORMATION FOR THE IMAGE USING THE BUILDING MASK, THE VEGETATION MASK, THE ROAD MASK, AND/OR ADDITIONAL INFORMATION
2312
USE THE CONTEXTUAL INFORMATION FOR THE IMAGE TO IDENTIFY A NUMBER OF REGIONS IN THE IMAGE WITHIN WHICH TO SEARCH FOR A TARGET OBJECT
2314
SEARCH FOR THE TARGET OBJECT IN THE NUMBER OF REGIONS USING A NUMBER OF AGENTS AND A PARTICLE-SWARM OPTIMIZATION PROCESS
END

FIG. 23

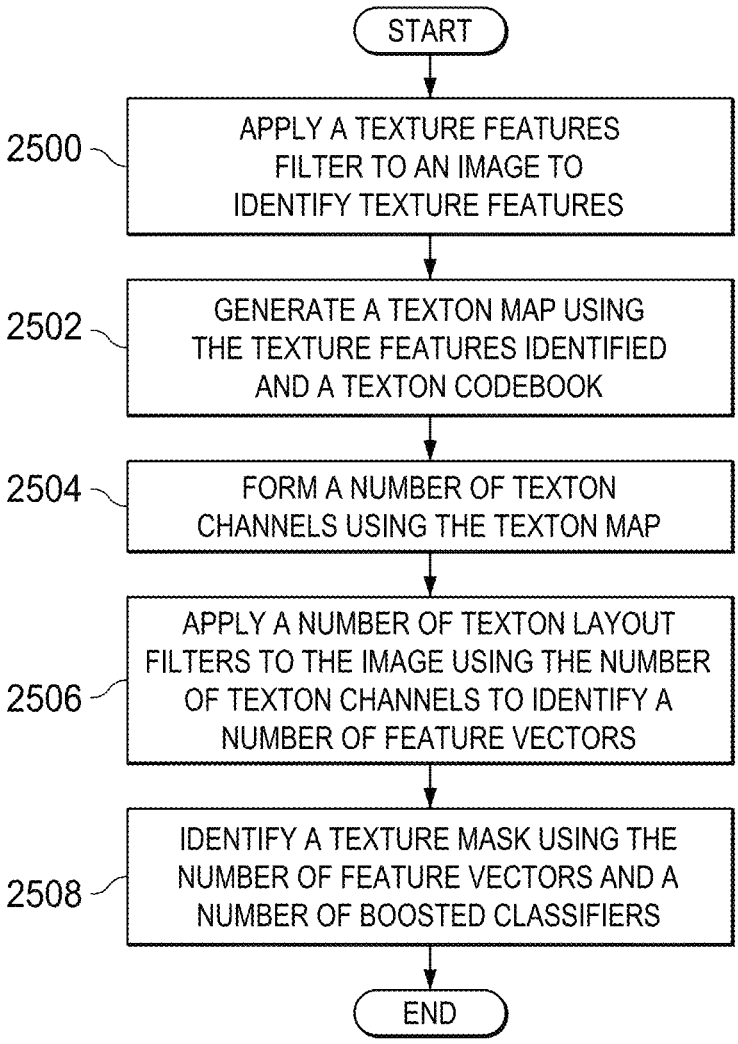

START
2500
APPLY A TEXTURE FEATURES FILTER TO AN IMAGE TO IDENTIFY TEXTURE FEATURES
2502
GENERATE A TEXTON MAP USING THE TEXTURE FEATURES IDENTIFIED AND A TEXTON CODEBOOK
2504
FORM A NUMBER OF TEXTON CHANNELS USING THE TEXTON MAP
2506
APPLY A NUMBER OF TEXTON LAYOUT FILTERS TO THE IMAGE USING THE NUMBER OF TEXTON CHANNELS TO IDENTIFY A NUMBER OF FEATURE VECTORS
2508
IDENTIFY A TEXTURE MASK USING THE NUMBER OF FEATURE VECTORS AND A NUMBER OF BOOSTED CLASSIFIERS
END

FIG. 25

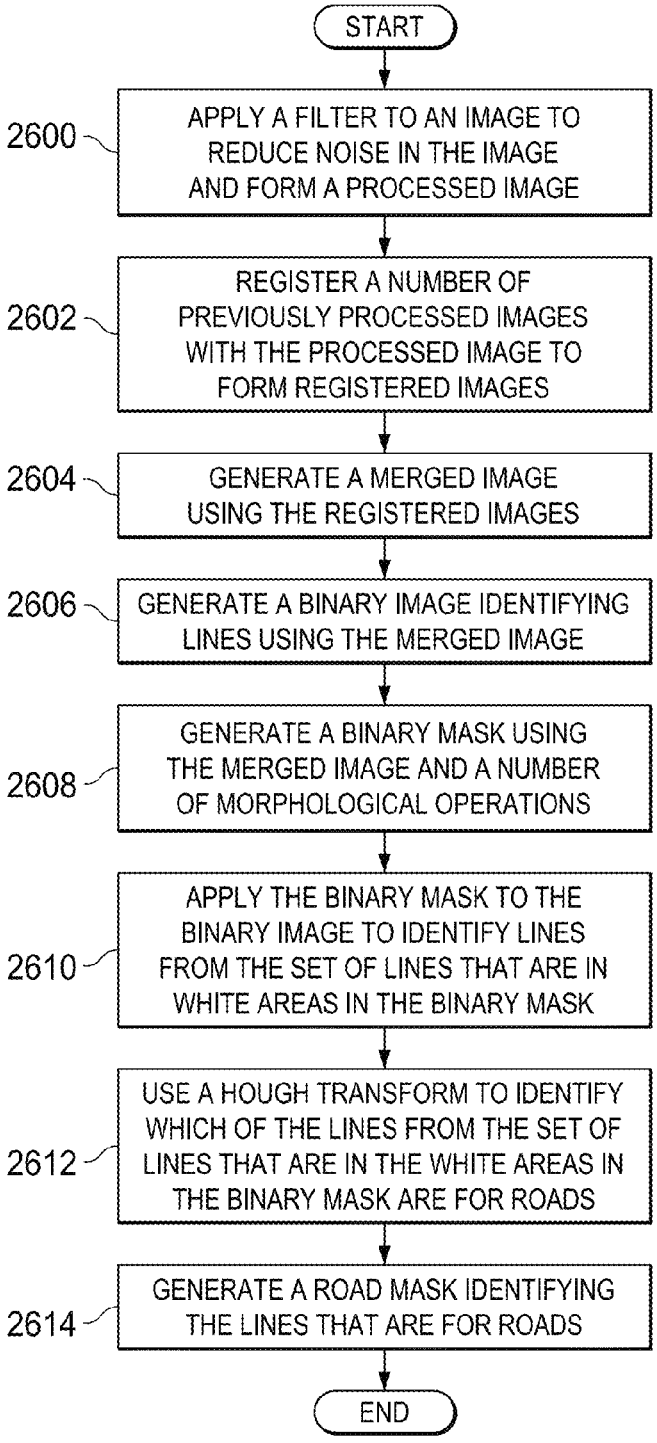
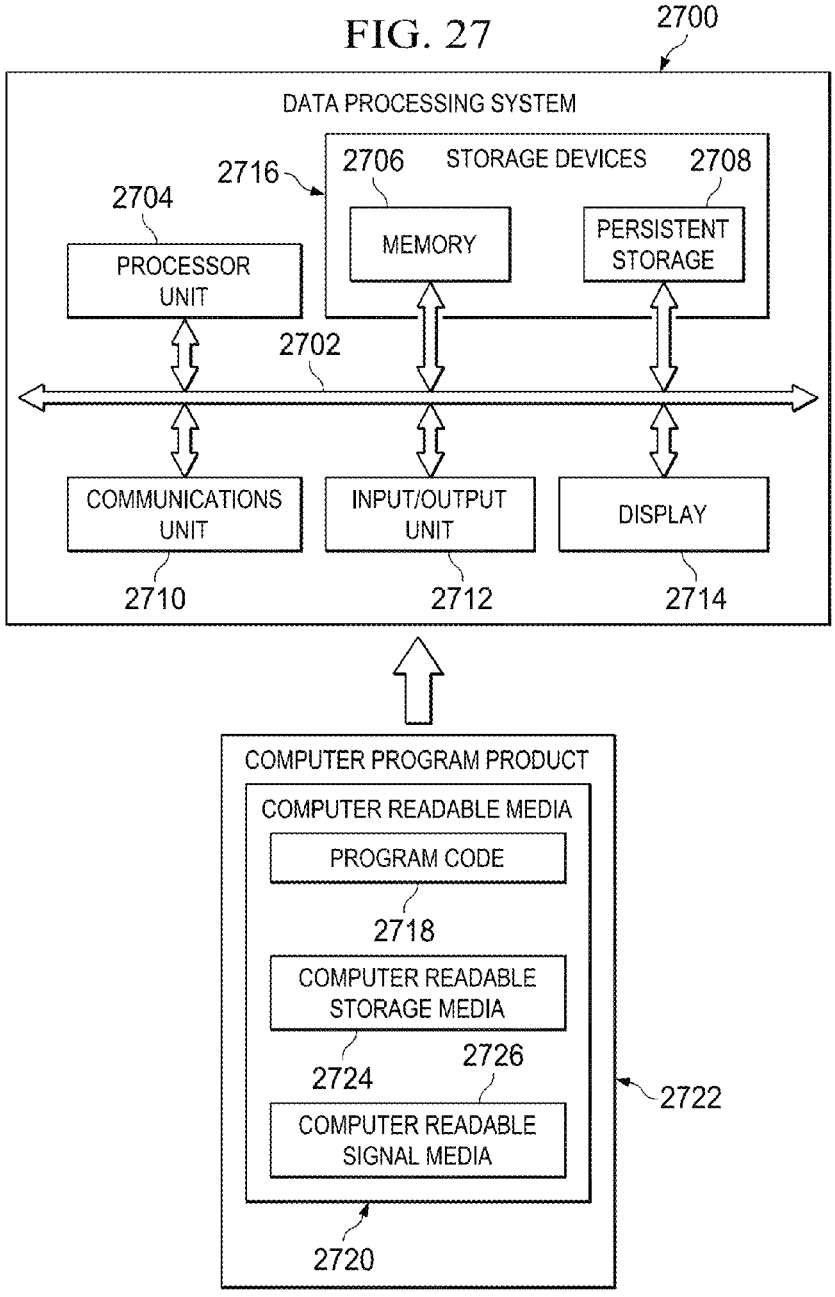

START
2600
APPLY A FILTER TO AN IMAGE TO REDUCE NOISE IN THE IMAGE AND FORM A PROCESSED IMAGE
2602
REGISTER A NUMBER OF PREVIOUSLY PROCESSED IMAGES WITH THE PROCESSED IMAGE TO FORM REGISTERED IMAGES
2604
GENERATE A MERGED IMAGE USING THE REGISTERED IMAGES
2606
GENERATE A BINARY IMAGE IDENTIFYING LINES USING THE MERGED IMAGE
2608
GENERATE A BINARY MASK USING THE MERGED IMAGE AND A NUMBER OF MORPHOLOGICAL OPERATIONS
2610
APPLY THE BINARY MASK TO THE BINARY IMAGE TO IDENTIFY LINES FROM THE SET OF LINES THAT ARE IN WHITE AREAS IN THE BINARY MASK
2612
USE A HOUGH TRANSFORM TO IDENTIFY WHICH OF THE LINES FROM THE SET OF LINES THAT ARE IN THE WHITE AREAS IN THE BINARY MASK ARE FOR ROADS
2614
GENERATE A ROAD MASK IDENTIFYING THE LINES THAT ARE FOR ROADS
END

FIG. 26

FIG. 27


2700
DATA PROCESSING SYSTEM
2716
2706
STORAGE DEVICES
2708
2704
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
2702
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
2710
2712
2714
COMPUTER PROGRAM PRODUCT
COMPUTER READABLE MEDIA
PROGRAM CODE
2718
COMPUTER READABLE STORAGE MEDIA
2724
2726
COMPUTER READABLE SIGNAL MEDIA
2722
2720

CONTEXT-BASED TARGET RECOGNITION

BACKGROUND INFORMATION

1. Field

The present disclosure relates generally to processing images and, in particular, to identifying objects in images. Still more particularly, the present disclosure relates to a method and apparatus for identifying target objects in images using contextual information in the images.

2. Background

Target recognition is the identification of one or more target objects in a number of images. The target objects to be identified may include, for example, without limitation, people, vehicles, buildings, structures, geographic features, and/or other types of objects. Target recognition may be used when performing various types of missions. These missions may include, for example, without limitation, surveillance, reconnaissance, weapons deployment, cargo drops, and/or other suitable types of missions.

Oftentimes, radar imaging is used to generate the images used in these types of missions. Synthetic aperture radar (SAR) imaging is a form of radar imaging in which an antenna may be mounted to a mobile platform. Typically, the mobile platform is an aerospace platform. An aerospace platform may be, for example, without limitation, an aircraft, an unmanned aerial vehicle, a helicopter, a missile, a satellite, a space shuttle, or some other suitable type of aerospace platform.

With synthetic aperture radar imaging, the mobile platform carrying a synthetic aperture radar system moves along a path. As the mobile platform moves along the path, an antenna in the synthetic aperture radar system sends pulses of electromagnetic radiation. This electromagnetic radiation is in the form of electromagnetic waves, which are also referred to as electromagnetic signals. These electromagnetic signals may have wavelengths, for example, from about 10 millimeters to about one meter.

The electromagnetic signals are directed at an area. The area may be, for example, an area of terrain, a block in a neighborhood, a section of a forest, a portion of a city, a plant, a bridge, or some other suitable type of area.

When these electromagnetic signals encounter a surface of the area, at least a portion of the electromagnetic signals is reflected off of the surface. The electromagnetic waves that are reflected off the surface may be referred to as backscatter, scattered electromagnetic waves, scattered electromagnetic signals, echo waves, or echoes.

As the mobile platform moves along the path over the area, the antenna detects the electromagnetic signals reflected off of the surface in response to the pulses sent by the antenna. The electromagnetic signals received at the antenna as the antenna moves along the path are processed to form an image of the area.

Additionally, synthetic aperture radar imaging may be implemented as inverse synthetic aperture radar imaging. This type of imaging is performed using a stationary antenna or an antenna mounted to a stationary platform. An image is generated for moving objects in the area observed over time.

With currently-available systems for target recognition using the number of images generated using synthetic aperture radar imaging, false identifications of objects may occur more often than desired. Corrective actions may need to be taken when false identifications occur. As a result, additional processing may occur to verify that the objects that have been identified are the target objects. Further, the time needed to recognize objects may be important when using that information to control the mobile platform or perform other actions that are time sensitive. The time needed to perform target recognition using currently-available systems may be greater than desired.

Therefore, it would be advantageous to have a method and apparatus that takes into account at least some of the issues discussed above, as well as possibly other issues.

SUMMARY

In one advantageous embodiment, a method is provided for identifying a target object. A group of objects is identified in an image. The group of objects provides a context for identifying the target object in the image. The target object is searched for in the image using the context provided by the group of objects.

In another advantageous embodiment, an apparatus comprises a context recognition module and a target recognition module. The context recognition module is configured to identify a group of objects in an image. The group of objects provides a context for identifying a target object in the image. The target recognition module is configured to search for the target object in the image using the context provided by the group of objects.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the advantageous embodiments are set forth in the appended claims. The advantageous embodiments, however, as well as a preferred mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an advantageous embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an illustration of an imaging environment in accordance with an advantageous embodiment;

FIG. **2** is an illustration of an imaging environment in accordance with an advantageous embodiment;

FIG. **3** is an illustration of a building detector in accordance with an advantageous embodiment;

FIG. **4** is an illustration of a detection of lines in an image in accordance with an advantageous embodiment;

FIG. **5** is an illustration of a cumulative histogram in accordance with an advantageous embodiment;

FIG. **6** is an illustration of a method for identifying bright areas in accordance with an advantageous embodiment;

FIG. **7** is an illustration of a binary image in which bright areas are present in accordance with an advantageous embodiment;

FIG. **8** is another illustration of a binary image in which bright areas are present in accordance with an advantageous embodiment;

FIG. **9** is another illustration of a binary image in which bright areas are present in accordance with an advantageous embodiment;

FIG. **10** is another illustration of a binary image in which bright areas are present in accordance with an advantageous embodiment;

FIG. **11** is an illustration of an image generated using a synthetic aperture radar imaging system in accordance with an advantageous embodiment;

FIG. **12** is an illustration of bright areas and shadows identified in an image in accordance with an advantageous embodiment;

FIG. **13** is an illustration of a building mask for an image in accordance with an advantageous embodiment;

FIG. **14** is an illustration of a vegetation detector in accordance with an advantageous embodiment;

FIG. **15** is an illustration of a process for identifying vegetation in accordance with an advantageous embodiment;

FIG. **16** is an illustration of a vegetation mask for an image in accordance with an advantageous embodiment;

FIG. **17** is an illustration of a binary image for use in identifying vegetation in accordance with an advantageous embodiment;

FIG. **18** is an illustration of a road detector in accordance with an advantageous embodiment;

FIG. **19** is an illustration of an image generated using a synthetic aperture radar imaging system in accordance with an advantageous embodiment;

FIG. **20** is an illustration of a processed image for use in identifying roads in accordance with an advantageous embodiment;

FIG. **21** is an illustration of a road mask for an image in accordance with an advantageous embodiment;

FIG. **22** is an illustration of a flowchart of a process for identifying a target object in accordance with an advantageous embodiment;

FIG. **23** is an illustration of a flowchart of a process for identifying a target object in an image in accordance with an advantageous embodiment;

FIG. **24** is an illustration of a flowchart of a process for detecting buildings in an image in accordance with an advantageous embodiment;

FIG. **25** is an illustration of a flowchart of a process for detecting vegetation in an image in accordance with an advantageous embodiment;

FIG. **26** is an illustration of a flowchart of a process for detecting roads in an image in accordance with an advantageous embodiment; and

FIG. **27** is an illustration of a data processing system in accordance with an advantageous embodiment.

DETAILED DESCRIPTION

Referring now to the figures, in FIG. **1**, an illustration of an imaging environment is depicted in accordance with an advantageous embodiment. In this illustrative example, imaging environment **100** is an environment in which images may be generated for area **102**. Area **102** includes terrain **104**, vegetation **106**, buildings **108**, road **110**, ground station **111**, and other objects within area **102**.

As depicted, unmanned aerial vehicle (UAV) **112** is present in imaging environment **100**. Radar imaging system **114** is mounted to unmanned aerial vehicle **112**. Radar imaging system **114** is a synthetic aperture radar (SAR) imaging system in this illustrative example.

Radar imaging system **114** is configured to send pulses of electromagnetic signals towards area **102** as unmanned aerial vehicle **112** moves along flight path **116** in the direction of arrow **118**. Further, radar imaging system **114** is configured to detect electromagnetic signals reflected off of the various surfaces in area **102**. These surfaces may include the surfaces of, for example, terrain **104**, vegetation **106**, buildings **108**, and/or road **110**.

Radar imaging system **114** processes the electromagnetic signals received as unmanned aerial vehicle **112** flies over area **102** along flight path **116** to generate an image of area **102**. This image may be used to identify a number of target objects in area **102**. As used herein, "a number of items" means one or more items. For example, "a number of target objects" means one or more target objects.

A target object may take the form of, for example, without limitation, at least one of a person, a vehicle, a tank, a truck, a motorcycle, a car, a missile, a mobile object, and/or some other suitable type of object. As used herein, the phrase "at least one of", when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one of each item in the list may be needed.

For example, "at least one of item A, item B, and item C" may include, for example, without limitation, item A, or item A and item B. This example also may include item A, item B, and item C, or item B and item C. In other examples, "at least one of" may be, for example, without limitation, two of item A, one of item B, and 10 of item C; four of item B and seven of item C; and other suitable combinations.

In this illustrative example, ground station **111** and/or unmanned aerial vehicle **112** may be configured to process images generated by radar imaging system **114** in accordance with an advantageous embodiment. In particular, ground station **111** and/or unmanned aerial vehicle **112** may process the images of area **102** to identify target objects in the images in accordance with an advantageous embodiment. This processing may be performed to reduce the number of false identifications of target objects in the images.

The different advantageous embodiments recognize and take into account a number of different considerations. For example, the different advantageous embodiments recognize and take into account that some currently-available methods for identifying a target object in an image search for the target object in a scene in the image using a pre-defined model for the target object. The different advantageous embodiments recognize and take into account that these methods may not use contextual information present in the scene in the image when identifying the target object.

Contextual information in an image may include, for example, an identification of buildings, vegetation, roads, and/or other structures in the scene in the image and/or other suitable information identified using the image. The different advantageous embodiments recognize and take into account that identifying the target object using contextual information identified in the image may reduce an amount of space in the scene in the image that needs to be searched as compared to using currently-available methods for identifying target objects.

Further, the different advantageous embodiments recognize and take into account that currently-available systems for identifying target objects may take more time and/or effort than desired. However, the different advantageous embodiments recognize and take into account that using contextual information in the image to identify the target object may allow target objects to be identified more quickly than with currently-available methods.

Additionally, the different advantageous embodiments recognize and take into account that noise and/or other undesired features may be present in an image. These undesired features may lead to a greater number of false identifications of target objects than desired. The different advantageous embodiments recognize and take into account that using contextual information in the image to identify the target object may reduce the number of false identifications of target objects as compared to currently available methods.

Thus, the different advantageous embodiments provide a method and apparatus for identifying a target object in an image. In particular, a method and apparatus for identifying a

target object in an image using contextual information identified in the image is provided. In one advantageous embodiment, a group of objects is identified in an image. The group of objects provides a context for identifying a target object in the image. The image is then searched for the target object using the context provided by the group of objects.

With reference now to FIG. **2**, an illustration of an imaging environment is depicted in accordance with an advantageous embodiment. Imaging environment **100** in FIG. **1** is an example of one implementation for imaging environment **200**. As depicted, imaging environment **200** includes platform **204**, imaging system **206**, area **208**, and image processing module **210**.

Platform **204** may be selected from one of, for example, without limitation, a mobile platform, a stationary platform, an aerial platform, a land-based platform, an aquatic-based platform, a space-based platform, and/or some other suitable type of platform. For example, platform **204** may take the form of an aircraft, an unmanned aerial vehicle, a missile, a helicopter, a spacecraft, a satellite, a space station, a submarine, a bus, a personnel carrier, a tank, a train, an automobile, a surface ship, a building, and/or some other suitable object. In these illustrative examples, platform **204** takes the form of mobile platform **211**.

In these depicted examples, imaging system **206** is associated with mobile platform **211**. A first component, such as imaging system **206**, may be considered to be associated with a second component, such as mobile platform **211**, by being secured to the second component, bonded to the second component, welded to the second component, fastened to the second component, mounted to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component using a third component. The first component may also be considered to be associated with the second component by being formed as part of and/or an extension of the second component.

As depicted, imaging system **206** is radar imaging system **209**. More specifically, radar imaging system **209** takes the form of synthetic aperture radar (SAR) imaging system **212** in these illustrative examples. Imaging system **206** may comprise antenna **214** and signal processing system **216**.

In these illustrative examples, antenna **214** is configured to send pulses **218** of first electromagnetic signals **220** towards area **208** in imaging environment **200** as mobile platform **211** moves along path **221** relative to area **208**. Path **221** may be over area **208**, to a side of area **208**, behind area **208**, and/or relative to area **208** in some other manner.

Area **208** may include, for example, without limitation, at least one of a region of terrain, a city, a block in a neighborhood, a town, an area of a city, a forest area, a mountainous region, a valley, an area of an ocean, a lake, a manufacturing facility, a power plant, a region of airspace, a region of space, and some other suitable type of area. Objects **222** may be present in area **208**. In these illustrative examples, objects **222** may include at least one of a building, a tree, a plant, a bush, a road, a highway, a structure, a sidewalk, a parking lot, a parking garage, a person, a feature of terrain in area **208**, and other suitable types of objects.

At least a portion of first electromagnetic signals **220** sent by antenna **214** are reflected off of surface **224** of area **208**. Surface **224** of area **208** includes the surface of any terrain in area **208** and the surfaces of objects **222** in area **208**.

In these depicted examples, the portion of first electromagnetic signals **220** reflected off of surface **224** of area **208** forms second electromagnetic signals **226**. Second electromagnetic signals **226** also may be referred to as backscatter, scattered electromagnetic signals, or echoes.

Antenna **214** is configured to detect second electromagnetic signals **226** over time as mobile platform **211** moves along path **221** relative to area **208**. Antenna **214** sends second electromagnetic signals **226** received at antenna **214** to signal processing system **216** for processing. Signal processing system **216** may be implemented using hardware, software, or a combination of the two in these examples.

As depicted, signal processing system **216** is configured to generate image **228** of area **208** using second electromagnetic signals **226**. In some illustrative examples, signal processing system **216** may be configured to perform preprocessing operations prior to generating image **228**. In other illustrative examples, signal processing system **216** may include information with image **228**. This information may include, for example, without limitation, a timestamp, a location of mobile platform **211**, and/or other suitable information.

In these illustrative examples, signal processing system **216** sends image **228** to image processing module **210**. Image processing module **210** may be implemented using hardware, software, or a combination of the two. In these illustrative examples, image processing module **210** may be implemented in computer system **230**. Computer system **230** may take the form of number of computers **231**.

Image processing module **210** may be located remote to imaging system **206** in these illustrative examples. For example, image processing module **210** may be located in mobile platform **211**. In other illustrative examples, image processing module **210** may be located at a ground station, control tower, or some other location remote to signal processing system **216**. As one illustrative example, when image processing module **210** is located at a ground station, signal processing system **216** sends image **228** to image processing module **210** using wireless communications link **232**.

In these illustrative examples, image processing module **210** comprises context recognition module **234** and target recognition module **235**. In these depicted examples, context recognition module **234** is configured to identify group of objects **236** in scene **237** in image **228**. As used herein, "a group of items" means one or more items. For example, "a group of objects" means one or more objects. Scene **237** is the portion of area **208** captured in image **228**.

Group of objects **236** provides context **238** for identifying target object **240** in image **228**. An object in group of objects **236** may be, for example, a building, vegetation, a road, or some other suitable type of object. Target object **240** may be any object that is an object of interest.

Context **238** for identifying target object **240** comprises the information present in scene **237** in image **228** that may be used to identify target object **240** in image **228**. Further, context **238** provided by group of objects **236** may be used to verify that an identification of an object in scene **237** is target object **240**. Number of regions **242** in image **228** for searching for target object **240** may be identified using context **238** provided by group of objects **236**.

In these illustrative examples, a region in number of regions **242** may be selected from within group of objects **236**, within a selected distance from group of objects **236**, outside of a selected distance from group of objects **236**, and/or relative to group of objects **236** in some other suitable manner.

In one illustrative example, context recognition module **234** forms number of masks **244** using context **238** provided by group of objects **236**. Context recognition module **234** uses number of masks **244** to identify number of regions **242** in image **228** for searching for target object **240**. Target rec-

ognition module **235** is configured to search for target object **240** in number of regions **242** in image **228** using number of masks **244**.

Further, target recognition module **235** is configured to search for target object **240** in number of regions **242** using number of agents **246**. Agent **248** is an example of one of number of agents **246**. Agent **248** is a search process that is configured to search for target object **240** within window **252** for agent **248**. A size and/or shape for window **252** may be selected based on the type of target object **240** for which the search is performed. Further, windows for different agents in number of agents **246** may have the same or different sizes and/or shapes.

Number of agents **246** may function as a swarm and search for target object **240** using particle-swarm optimization (PSO) process **250**. This process optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. For example, a placement of window **252** for agent **248** relative to image **228** may be a candidate solution for the identification of target object **240**. The candidate solution also may be referred to as a particle.

Window **252** is moved within number of regions **242** in image **228** according to simple mathematical formulae for a position and velocity for window **252**. In these illustrative examples, agent **248** identifies a best known position for window **252** in number of regions **242**. Further, other agents in number of agents **246** identify best known positions for windows corresponding to these other agents. These best known positions are updated as better positions are identified.

The position and/or movement of window **252** within number of regions **242** in image **228** is guided by the best known position identified by agent **248** and the updated best known positions for the other agents in number of agents **246**. In this manner, number of agents **246** may move as a swarm towards the best position in number of regions **242** for identifying target object **240**.

In some illustrative examples, context **238** for identifying target object **240** may also be provided by additional information **254**. Additional information **254** may include information obtained from sources other than image **228**. Additional information **254** may include, for example, without limitation, intelligence information, geographical data, maps, mission details, weather data, location information, and/or other suitable types of information.

In this manner, target recognition module **235** uses context **238** provided by group of objects **236** to identify target object **240** in image **228** more quickly as compared to currently-available methods that may search all of image **228** for target object **240**.

Further, using target recognition module **235** may reduce the possibility of a false identification of target object **240** in image **228**. For example, target object **240** to be identified in image **228** may be a tank. In this example, group of objects **236** provide context **238** for identifying the tank. Group of objects **236** may comprise, for example, vegetation, such as trees. Number of regions **242** is identified using context **238** provided by the trees such that target recognition module **235** does not identify the tank within the trees.

The illustration of imaging environment **200** in FIG. **2** is not meant to imply physical or architectural limitations to the manner in which an advantageous embodiment may be implemented. Other components in addition to and/or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in an advantageous embodiment.

For example, in some illustrative examples, platform **204** may be a stationary platform instead of mobile platform **211**. In other illustrative examples, a portion of image processing module **210** may be part of signal processing system **216** in imaging system **206**. A portion of image processing module **210** may be some or all of image processing module **210** in these illustrative examples.

Further, in other illustrative examples, target recognition module **235** may be configured to identify other target objects in addition to and/or in place of target object **240**. In still other illustrative examples, target recognition module **235** may use other processes, in addition to and/or in place of particle-swarm optimization process **250** to search for target object **240** in image **228**.

With reference now to FIG. **3**, an illustration of a building detector is depicted in accordance with an advantageous embodiment. Building detector **300** may be implemented in context recognition module **234** in FIG. **2**. In particular, building detector **300** is configured to identify buildings that may be in image **228** in FIG. **2**. Any buildings that are identified may form a portion of group of objects **236** in FIG. **2**.

In this illustrative example, building detector **300** comprises noise filter **302**, line detector **304**, area detector **306**, shadow detector **308**, and classification module **310**. Noise filter **302** is configured to reduce noise **312** that may be present in image **228**. The reduction of noise **312** may substantially remove noise in image **228** in a manner that provides a desired quality for image **228**.

Noise **312** may take the form of, for example, speckle noise **314**. Speckle noise **314** may be a granular noise that is present in image **228**. Speckle noise **314** may be caused by undesired random fluctuations in second electromagnetic signals **226** received at antenna **214** in imaging system **206** in FIG. **2**.

As depicted, after noise filter **302** processes image **228** to reduce noise **312**, processed image **316** is present. Line detector **304** is configured to identify set of lines **318** in processed image **316**. As used herein, "a set of items" may be zero or more items. For example, "a set" may be an empty or null set. In this depicted example, lines in set of lines **318** are bright lines.

In this illustrative example, line detector **304** may be implemented using an algorithm developed by Carsten Steger. This algorithm extracts set of lines **318** from processed image **316** and estimates a width for each of set of lines **318**. This algorithm also identifies a position for each line in set of lines **318** and estimates the width for each line with a sub-pixel level of accuracy.

Further, area detector **306** is configured to identify set of bright areas **324** in this illustrative example. Set of bright areas **324** is identified using number of thresholds **326** for intensity **327** in processed image **316**. Intensity **327** for each pixel in processed image **316** may be from about zero to about 255. In particular, a portion of set of bright areas **324** may be identified for each threshold in number of thresholds **326** applied to processed image **316**.

In this illustrative example, number of thresholds **326** is selected based on cumulative histogram **329** for processed image **316**. Cumulative histogram **329** plots level of intensity versus a cumulative percentage of pixels in processed image **316**.

In particular, first threshold **328** in number of thresholds **326** may be selected based on percentage **330**. Percentage **330** is selected using cumulative histogram **329**. Percentage **330** is the percentage of pixels that are to be included in the process for identifying set of bright areas **324**. Percentage **330** is selected to be between about 85 percent and about 95 percent.

As one illustrative example, first threshold **328** may be selected as the level of intensity at which percentage **330** is about 90 percent.

In this illustrative example, other thresholds in number of thresholds **326** may be selected by substantially equally dividing the interval between first threshold **328** and a highest level of intensity **327** in processed image **316** by a total number of thresholds in number of thresholds **326**.

Area detector **306** applies number of thresholds **326** to processed image **316** to identify number of binary images **331**. A binary image is an image in which each pixel in the binary image has only two values. These two values are first value **332** and second value **334**.

In this illustrative example, first value **332** for the pixel indicates that the intensity for that pixel is less than the particular threshold from number of thresholds **326** applied to the pixel. Second value **334** for the pixel indicates that the intensity for that pixel is greater than the particular threshold from number of thresholds **326** applied to the pixel. Pixels in a binary image in number of binary images **331** that have second value **334** are identified as being part of a bright area.

Set of bright areas **324** may be present in number of binary images **331**. A binary image in number of binary images **331** may include bright areas that are not present in other binary images in number of binary images **331**. In some cases, no bright areas may be present in one or more of number of binary images **331**.

Of course, other processes for identifying set of bright areas **324** may be used. For example, in some cases, area detector **306** may be configured to identify set of bright areas **324** using image **228** instead of processed image **316**.

In this illustrative example, shadow detector **308** is configured to identify set of shadows **336**. Shadow detector **308** identifies set of shadows **336** in a manner similar to the manner in which area detector **306** identifies set of bright areas **324**. For example, shadow detector **308** applies number of thresholds **326** to processed image **316**. First threshold **328** in number of thresholds **326** is selected based on percentage **330**. Percentage **330** may be selected to be between about 20 percent and about 25 percent.

Other thresholds in number of thresholds **326** are selected by substantially equally dividing the interval between first threshold **328** and a lowest level of intensity **327** in processed image **316** by the total number of thresholds in number of thresholds **326**. Number of thresholds **326** may be applied to processed image **316** to obtain number of binary images **331**. Set of shadows **336** is present in number of binary images **331**.

In this illustrative example, classification module **310** is configured to process set of lines **318**, set of bright areas **324**, and set of shadows **336** to identify which of the items in these sets are produced by buildings in image **228**. Classification module **310** identifies set of buildings **350** using set of lines **318**, set of bright areas **324**, set of shadows **336**, and/or other suitable information.

Further, classification module **310** may generate building mask **352** by identifying set of buildings **350** in image **228**. Building mask **352** may include, for example, locations of set of buildings **350** in image **228**.

The illustration of building detector **300** in FIG. **3** is not meant to imply limitations to the manner in which an advantageous embodiment may be implemented. For example, in some illustrative examples, thresholds in number of thresholds **326** other than first threshold **328** may be selected by identifying the centroids of clusters of pixels identified based on intensity. The clusters may be identified using, for example, a K-means clustering algorithm and/or other suitable clustering algorithms.

With reference now to FIG. **4**, an illustration of a detection of lines in an image is depicted in accordance with an advantageous embodiment. In this illustrative example, lines **400** have been identified in image **402**. The detection of lines **400** may have been made by, for example, line detector **304** in building detector **300** in FIG. **3**.

Lines **400** may be filtered to identify a set of lines, such as set of lines **318** in FIG. **3**. Lines **400** may be filtered using a number of criteria. In particular, any line in lines **400** having a length in image **402** that corresponds to a length of at least about 10 meters in the real world is selected. The Hough transform may be applied to these selected lines to further filter lines **400** to identify the set of lines. Using the Hough transform, any line having a substantially straight portion with a length corresponding to a length of at least about 10 meters in the real world is included in the set of lines.

With reference now to FIG. **5**, an illustration of a cumulative histogram is depicted in accordance with an advantageous embodiment. In this illustrative example, cumulative histogram **500** is an example of one implementation for cumulative histogram **329** in FIG. **3**.

As depicted, cumulative histogram **500** has horizontal axis **502** and vertical axis **504**. Horizontal axis **502** is intensity **506**. Vertical axis **504** is percentage of pixels **508**.

In this illustrative example, first threshold **510**, T_o, in number of thresholds **512** is selected based on percentage **514**, P_o. Other thresholds in number of thresholds **512** are selected by dividing the interval along horizontal axis **502** between first threshold **510** and highest intensity **516**, N, by the total number of thresholds in number of thresholds **512**.

With reference now to FIG. **6**, an illustration of a method for identifying bright areas is depicted in accordance with an advantageous embodiment. In this illustrative example, intensity **600** is the intensity for pixels in section **601** of an image, such as processed image **316** in FIG. **3**.

First level of intensity **602** is a first threshold in a number of thresholds to be applied to the image. Second level of intensity **604** represents a second threshold in the number of thresholds. Third level of intensity **606** represents a third threshold in the number of thresholds. Fourth level of intensity **608** represents a fourth threshold in the number of thresholds.

As depicted in this example, first portion **610** of section **601** is the portion of section **601** having pixels with an intensity substantially equal to or greater than first level of intensity **602**. Second portion **612** of section **601** is the portion of section **601** having pixels with an intensity substantially equal to or greater than second level of intensity **604**.

Third portion **614** of section **601** is the portion of section **601** having pixels with an intensity substantially equal to or greater than third level of intensity **606**. Fourth portion **616** of section **601** is the portion of section **601** having pixels with an intensity substantially equal to or greater than fourth level of intensity **608**.

With reference now to FIGS. **7-10**, illustrations of binary images in which bright areas are present are depicted in accordance with an advantageous embodiment. In these illustrative examples, these binary images may be generated by an area detector, such as area detector **306** in building detector **300** in FIG. **3**. In particular, these binary images may be generated by filtering a processed image, such as processed image **316** in FIG. **3**, for varying levels of intensity.

Turning now to FIG. **7**, binary image **700** is generated by filtering the processed image for pixels having an intensity

substantially equal to or greater than first level of intensity **602** in FIG. **6**. The portions of the processed image having pixels with an intensity substantially equal to or greater than first level of intensity **602** are represented in binary image **700** as bright areas **702**.

Turning now to FIG. **8**, binary image **800** is generated by filtering the processed image for pixels having an intensity substantially equal to or greater than second level of intensity **604** in FIG. **6**. The portions of the processed image having pixels with an intensity substantially equal to or greater than second level of intensity **604** are represented in binary image **800** as bright areas **802**.

Similarly, in FIG. **9**, binary image **900** is generated by filtering the processed image for pixels having an intensity substantially equal to or greater than third level of intensity **606** in FIG. **6**. The portions of the processed image having pixels with an intensity substantially equal to or greater than third level of intensity **606** are represented in binary image **900** as bright areas **902**.

Further, in FIG. **10**, binary image **1000** is generated by filtering the processed image for pixels having an intensity substantially equal to or greater than fourth level of intensity **608** in FIG. **6**. The portions of the processed image having pixels with an intensity substantially equal to or greater than fourth level of intensity **608** are represented in binary image **1000** as bright areas **1002**.

In these illustrative examples, bright areas **702** in FIG. **7**, bright areas **802** in FIG. **8**, bright areas **902** in FIG. **9**, and bright areas **1002** in FIG. **10** are processed to identify bright areas that represent buildings. In particular, a confidence score is assigned to each bright area.

The confidence score may be identified based on shape descriptors, such as, for example, elliptical Fourier descriptors, for the bright areas. These types of shape descriptors may be used given that buildings typically produce a rectangular or L-shaped bright area. The confidence score may be identified based on how closely the shape for a bright area matches a shape descriptor for the bright area. Further, the confidence score may be identified based on training tests for typical bright areas produced by buildings.

In one illustrative example, the confidence scores for a bright area in each of the different levels of intensity may be summed to identify a confidence score for the bright area. This confidence score may then be compared to a selected threshold. A bright area having a confidence score greater than the selected threshold may be identified as a bright area that may have been produced by a building.

In these illustrative examples, shadows that may have been produced by buildings are identified in a manner similar to the way in which bright areas that may have been produced by buildings are identified.

With reference now to FIG. **11**, an illustration of an image generated using a synthetic aperture radar imaging system is depicted in accordance with an advantageous embodiment. In this illustrative example, image **1100** is an example of one implementation for image **228** generated using synthetic aperture radar imaging system **212** in FIG. **2**. As depicted, buildings **1102** are present in image **1100**.

Turning now to FIG. **12**, an illustration of bright areas and shadows identified in image **1100** is depicted in accordance with an advantageous embodiment. In this illustrative example, bright areas **1200** and shadows **1202** are identified in image **1100**.

Bright areas **1200** may be identified by, for example, area detector **306** in building detector **300** in FIG. **3**. Shadows **1202** may be identified by, for example, shadow detector **308** in building detector **300** in FIG. **3**. In this illustrative example, the presence of both bright areas **1200** and shadows **1202** are used to identify buildings **1204** in image **1100**.

Further, as depicted, heights **1206** may be identified for buildings **1204** identified in image **1100**. Heights **1206** are estimations of the actual heights for these buildings. In this illustrative example, heights **1206** may be calculated by building detector **300** using the heights of shadows **1202**.

With reference now to FIG. **13**, an illustration of a building mask for image **1100** is depicted in accordance with an advantageous embodiment. In this illustrative example, building mask **1300** is overlaid on image **1100**. Building mask **1300** is an example of one implementation for building mask **352** in FIG. **3**.

As depicted, building mask **1300** identifies buildings **1302** in locations **1304** in image **1100**. Buildings **1302** are identified based on the confidence scores for lines, bright areas, and/or shadows identified for image **1100**. In particular, a building in buildings **1302** may be represented by the identification of a line, a bright area, a shadow, or some combination of these features.

Building mask **1300** may be used when identifying a target object in image **1100**. In other words, portions of image **1100** not identified as buildings **1302** may be searched for the target object.

With reference now to FIG. **14**, an illustration of a vegetation detector is depicted in accordance with an advantageous embodiment. In this illustrative example, vegetation detector **1400** may be implemented in context recognition module **234** in FIG. **2**. In particular, vegetation detector **1400** is configured to identify vegetation that may be present in image **228** in FIG. **2**. Vegetation that is identified may form a portion of group of objects **236** in FIG. **2**.

In this illustrative example, vegetation detector **1400** processes image **228** from FIG. **2** using texture features filter **1402**, number of texton layout filters **1404**, and boosted classifiers **1406**. Boosted classifiers **1406** may be a number of boosted classifiers in some illustrative examples. Vegetation detector **1400** applies texture features filter **1402** to image **228**. Texture features filter **1402** allows the portions of image **228** that substantially match predefined texture features to be extracted.

In this depicted example, a texture feature is a feature in image **228**, such as a pattern, that may represent a particular texture for vegetation and/or background in image **228**. A texture feature may also be referred to as a texton. A particular texture may be, for example, without limitation, grass, foliage, human skin, a road, sky, clouds, and/or some other suitable type of texture.

Vegetation detector **1400** identifies texture features **1408** in image **228** in response to applying texture features filter **1402** to image **228**. Vegetation detector **1400** uses texture features **1408** to generate texton map **1410**. Texton map **1410** identifies where texture features **1408** are located in image **228**.

For example, vegetation detector **1400** may group texture features **1408** together based on type using texton codebook **1411**. This grouping may also be referred to as clustering and assignment. Texton codebook **1411** is an identification of the types of texture features that might be identified in the image.

Each group of texture features **1408** of a particular type is the output of applying texture features filters **1402** to image **228** and corresponds to a shape in number of shapes **1412** on texton map **1410**. Of course, multiple groups of the same type of texture features may be present.

In this illustrative example, number of shapes **1412** may be a number of rectangular shapes. This number of rectangular shapes may have varying lengths and/or widths. Of course, in other illustrative examples, number of shapes **1412** may take

the form of other shapes, such as, for example, circular shapes, elliptical shapes, and/or other suitable types of shapes.

Further, in this depicted example, number of shapes **1412** may have number of colors **1414**. Each of number of colors **1414** corresponds to a particular type of texture feature. As one illustrative example, when number of shapes **1412** represents texture features of two different types, a portion of number of shapes **1412** will have a first color, while a second portion of number of shapes **1412** has a second color. In some cases, all of number of shapes **1412** may have the same color when all of number of shapes **1412** represents texture features of a same type.

As depicted in this example, vegetation detector **1400** uses texton map **1410** to form number of texton channels **1416**. Each texton channel in number of texton channels **1416** is a map for texture features of a particular type. In other words, each texton channel includes the shapes in number of shapes **1412** representing a particular type of texture feature. In this manner, all of the shapes from number of shapes **1412** in a particular texton channel have the same color.

In this illustrative example, vegetation detector **1400** applies number of texton layout filters **1404** to image **228** using number of texton channels **1416**. In particular, each of number of texton layout filters **1404** corresponds to one of number of texton channels **1416**. In other words, each of number of texton layout filters **1404** is for a particular type of texture feature.

Texton layout filter **1418** is an example of one of number of texton layout filters **1404**. Texton layout filter **1418** is a combination of a region in number of regions **1420** and a corresponding pixel marker in number of pixel markers **1422**. The region has a fixed size and position with respect to the corresponding pixel marker. Texton layout filter **1418** compares each pixel in image **228** where a pixel marker is placed with image information inside the corresponding region in number of regions **1420**.

Vegetation detector **1400** generates number of feature vectors **1424** in response to applying texton layout filter **1418**. A feature vector in number of feature vectors **1424** is an n-dimensional vector of numerical features that represent some object or texture in image **228**.

Number of feature vectors **1424** is processed using boosted classifiers **1406** to identify texture mask **1426**. Boosted classifiers **1406** are texture classifiers that have been identified using boosting algorithms, such as, for example, without limitation, adaptive boosting (AdaBoost), linear programming boosting (LPBoost), and/or other suitable types of boosting algorithms.

Texture mask **1426** identifies textures **1428** in image **228**. Textures **1428** may be color-coded in this illustrative example. For example, grass may be represented in texture mask **1426** by a first color, while sky is represented by a second color, and trees are presented by a third color. When texture mask **1426** is generated for only vegetation textures, texture mask **1426** may be a vegetation mask.

With reference now to FIG. **15**, an illustration of an image generated using a synthetic aperture radar imaging system is depicted in accordance with an advantageous embodiment. In this illustrative example, image **1500** is an example of one implementation for image **228** generated using synthetic aperture radar imaging system **212** in FIG. **2**. As depicted, vegetation **1502** is present in image **1500**.

Turning now to FIG. **16**, an illustration of a confidence mask for use in identifying vegetation is depicted in accordance with an advantageous embodiment. In this illustrative example, confidence mask **1600** may be generated by a vegetation detector, such as, for example, vegetation detector **1400** in FIG. **14**.

Confidence mask **1600** is an image in which the level of intensity for each pixel is based on a confidence score for a corresponding pixel in image **1500** in FIG. **15**. This confidence score identifies the confidence with which the pixel in image **1500** represents vegetation. A higher level of intensity corresponds to a higher level of confidence that the corresponding pixel is for vegetation as compared to a lower level of intensity.

A vegetation mask may be identified by applying a threshold to confidence mask **1600**. In other words, pixels in confidence mask **1600** having intensities greater than a selected threshold may be identified as vegetation.

With reference now to FIG. **17**, an illustration of a vegetation mask for an image is depicted in accordance with an advantageous embodiment. In this illustrative example, vegetation mask **1700** is overlaid on image **1500**. Vegetation mask **1700** may be generated by a vegetation detector, such as, for example, vegetation detector **1400** in FIG. **14**. Vegetation mask **1700** is identified by applying a threshold to confidence mask **1600** in FIG. **16**.

With reference now to FIG. **18**, an illustration of a road detector is depicted in accordance with an advantageous embodiment. Road detector **1800** may be implemented in context recognition module **234** in FIG. **2**. In particular, road detector **1800** is configured to identify roads that may be present in image **228** in FIG. **2**. Roads that are identified may form a portion of group of objects **236** in FIG. **2**.

As depicted, road detector **1800** includes filter **1802**, registration module **1803**, line detector **1804**, morphological operations module **1806**, and Hough transform **1826**. Filter **1802** is configured to reduce noise in the form of speckle noise from image **228** to form processed image **1810**. Of course, filter **1802** may be configured to reduce other types of noise in addition to and/or in place of speckle noise.

Registration module **1803** is configured to receive processed image **1810**. Registration module **1803** registers number of previous images **1811** with processed image **1810** to form registered images **1812**. Number of previous images **1811** includes one or more previously filtered synthetic aperture radar images. Registered images **1812** are number of previous images **1811** aligned with and overlaid over processed image **1810**.

Further, registration module **1803** performs merging operations **1814** to form merged image **1816** using registered images **1812**. Merging operations **1814** include selecting the maximum value of corresponding pixels in registered images **1812** as the value for the corresponding pixels in merged image **1816**.

Shadows may have a level of intensity similar to roads. However, shadows cast by objects, such as buildings, structures, vegetation, and/or other types of objects, may be in different locations and/or have different sizes in registered images when the images are generated from different viewpoints and/or by different camera systems. As a result, a pixel for a shadow cast by an object, such as a building, in processed image **1810** may correspond to a pixel in another image in registered images **1812** that is not for the same shadow.

Further, lines that may be identified for roads may be in substantially the same locations in registered images. In this manner, a pixel for a road in processed image **1810** may correspond to a pixel for the same road in the other images in registered images **1812**.

In this manner, merging operations **1814** reduces the presence of undesired shadows and/or other features that may cause a false identification of roads.

Merged image **1816** is sent to both line detector **1804** and morphological operations module **1806**. Line detector **1804** is configured to detect lines **1818**. Line detector **1804** may be implemented using the algorithm developed by Carsten Steger, which is similar to line detector **304** in FIG. **3**. However, in these illustrative examples, lines **1818** are dark lines. In this illustrative example, line detector **1804** generates binary image **1819**. In binary image **1819**, pixels corresponding to lines **1818** have a value of "1".

Morphological operations module **1806** applies selected threshold **1820** to merged image **1816** to generate binary image **1822**. In this illustrative example, selected threshold **1820** may be a low level of intensity for the pixels in merged image **1816**. In particular, a pixel in binary image **1822** has a value of "1" when the corresponding pixel in merged image **1816** has a value less than selected threshold **1820**.

Additionally, morphological operations module **1806** is configured to process binary image **1822** using morphological image processing to form binary mask **1824**. Morphological image processing may include morphological operations, such as, for example, without limitation, blob analysis, erosion, dilation, opening, closing, and/or other suitable types of morphological operations. Binary mask **1824** may be white areas in which pixels have a value of "1". These white areas are areas that may potentially be roads.

Road mask generation module **1808** is configured to apply binary mask **1824** to binary image **1819** to identify which of lines **1818** are in the white areas of binary mask **1824**. Road mask generation module **1808** uses Hough transform **1826** to identify which of the lines in the white areas of binary mask **1824** may be for roads. In particular, Hough transform **1826** is used to identify set of roads **1828** based on which of the lines in the wire areas of binary mask **1824** are substantially straight lines for roads. Based on the results of Hough transform **1826**, road mask generation module **1808** generates road mask **1830** identifying set of roads **1828**.

With reference now to FIG. **19**, an illustration of an image generated using a synthetic aperture radar imaging system is depicted in accordance with an advantageous embodiment. In this illustrative example, image **1900** may be generated using a synthetic aperture radar imaging system, such as synthetic aperture radar imaging system **212** in FIG. **2**. As depicted, road **1902** is present in image **1900**.

Turning now to FIG. **20**, an illustration of a processed image for use in identifying roads is depicted in accordance with an advantageous embodiment. In this illustrative example, binary image **2000** may be generated using a road detector, such as road detector **1800** in FIG. **18**. In particular, binary image **2000** is an example of one implementation for binary image **1819** in FIG. **18**.

With reference now to FIG. **21**, an illustration of a road mask for an image is depicted in accordance with an advantageous embodiment. In this illustrative example, road mask **2100** may be generated by a road detector, such as road detector **1800** in FIG. **18**. Road mask **2100** is overlaid on image **1900** from FIG. **19**.

With reference now to FIG. **22**, an illustration of a flowchart of a process for identifying a target object is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **22** may be implemented using image processing module **210** in FIG. **2**.

The process begins by receiving an image (operation **2200**). The image received may have been generated using, for example, synthetic aperture radar imaging system **212** in FIG. **2**. The process then preprocesses the image to reduce noise in the image (operation **2202**). In operation **2202**, the image may be preprocessed to reduce noise in the form of speckle noise in this illustrative example.

Next, the process identifies a group of objects in the image (operation **2204**). The group of objects provides a context for identifying the target object. The group of objects may include, for example, buildings, roads, vegetation, and/or other objects. The process then identifies a number of regions in the image to search for the target object based on the context from the group of objects (operation **2206**). Thereafter, the process searches for the target object in the image using the context provided by the group of objects (operation **2208**), with the process terminating thereafter.

With reference now to FIG. **23**, an illustration of a process for identifying a target object in an image is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **23** may be implemented using image processing module **210** in FIG. **2**. Further, this process may be a more-detailed process of the process illustrated in FIG. **22**.

The process begins by receiving an image generated using a synthetic aperture radar imaging system (operation **2300**). The process then preprocesses the image to reduce noise in the image (operation **2302**). Next, the process generates a building mask for the image (operation **2304**). The process then generates a vegetation mask for the image (operation **2306**). Then, the process generates a road mask for the image (operation **2308**).

Thereafter, the process identifies contextual information for the image using the building mask, the vegetation mask, the road mask, and/or additional information (operation **2310**). The additional information may include, for example, weather data, traffic data, geographical information, maps, satellite images, mission details, and/or other suitable types of information.

Next, the process uses the contextual information for the image to identify a number of regions in the image within which to search for a target object (operation **2312**). A region in the number of regions may be, for example, within a selected distance from one or more of the building mask, the vegetation mask, and the road mask. In some illustrative examples, a region may be within the road mask when the target object is a vehicle traveling on a road.

The process then searches for the target object in the number of regions using a number of agents and a particle-swarm optimization process (operation **2314**), with the process terminating thereafter. In operation **2314**, each agent in the number of agents searches for the target object within a window for the agent.

With reference now to FIG. **24**, an illustration of a process for detecting buildings in an image is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **24** may be implemented using, for example, building detector **300** in FIG. **3**. Further, this process may be used to implement operation **2304** in FIG. **23**.

The process begins by identifying a set of lines in an image (operation **2400**). In operation **2400**, the image is a processed image. In particular, the processed image has been processed to substantially remove noise, such as speckle noise, from the image.

The process then identifies a set of bright areas in the image (operation **2402**). Next, the process identifies a set of shadows in the image (operation **2404**). Thereafter, the process identifies a set of buildings in the image using the set of lines, the set of bright areas, and the set of shadows (operation **2406**). The process generates a building mask for the image that

identifies the set of buildings and locations for the set of buildings in the image (operation **2408**), with the process terminating thereafter.

With reference now to FIG. **25**, an illustration of a flowchart of a process for detecting vegetation in an image is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **25** may be implemented using, for example, vegetation detector **1400** in FIG. **14**. Further, this process may be used to implement operation **2306** in FIG. **23**.

The process begins by applying a texture features filter to an image to identify texture features (operation **2500**). The process then generates a texton map using the texture features identified and a texton codebook (operation **2502**). Next, the process forms a number of texton channels using the texton map (operation **2504**).

The process applies a number of texton layout filters to the image using the number of texton channels to identify a number of feature vectors (operation **2506**). Thereafter, the process identifies a texture mask using the number of feature vectors and a number of boosted classifiers (operation **2508**), with the process terminating thereafter.

With reference now to FIG. **26**, an illustration of a flowchart of a process for detecting roads in an image is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **26** may be implemented using, for example, road detector **1800** in FIG. **18**.

The process begins by applying a filter to an image to reduce noise in the image and form a processed image (operation **2600**). The noise may be in the form of, for example, speckle noise. The process registers a number of previously processed images with the processed image to form registered images (operation **2602**). The process generates a merged image using the registered images (operation **2604**).

Thereafter, the process generates a binary image identifying lines using the merged image (operation **2606**). These lines represent the dark lines from the processed image. The process generates a binary mask using the merged image and a number of morphological operations (operation **2608**). Next, the process applies the binary mask to the binary image to identify lines from the set of lines that are in white areas in the binary mask (operation **2610**).

The process then uses a Hough transform to identify which of the lines from the set of lines that are in the white areas in the binary mask are for roads (operation **2612**). Thereafter, the process generates a road mask identifying the lines that are for roads (operation **2614**), with the process terminating thereafter.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus and methods in an advantageous embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step. For example, one or more of the blocks may be implemented as program code, in hardware, or a combination of the program code and hardware. When implemented in hardware, the hardware may, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams.

In some alternative implementations of an advantageous embodiment, the function or functions noted in the block may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Turning now to FIG. **27**, an illustration of a data processing system is depicted in accordance with an advantageous embodiment. In this illustrative example, data processing system **2700** may be used to implement one or more of number of computers **231** in FIG. **2**. Data processing system **2700** includes communications fabric **2702**, which provides communications between processor unit **2704**, memory **2706**, persistent storage **2708**, communications unit **2710**, input/output (I/O) unit **2712**, and display **2714**.

Processor unit **2704** serves to execute instructions for software that may be loaded into memory **2706**. Processor unit **2704** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular implementation. A number, as used herein with reference to an item, means one or more items. Further, processor unit **2704** may be implemented using a number of heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit **2704** may be a symmetric multiprocessor system containing multiple processors of the same type.

Memory **2706** and persistent storage **2708** are examples of storage devices **2716**. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, data, program code in functional form, and/or other suitable information either on a temporary basis and/or a permanent basis. Storage devices **2716** may also be referred to as computer readable storage devices in these examples. Memory **2706**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **2708** may take various forms, depending on the particular implementation.

For example, persistent storage **2708** may contain one or more components or devices. For example, persistent storage **2708** may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **2708** also may be removable. For example, a removable hard drive may be used for persistent storage **2708**.

Communications unit **2710**, in these examples, provides for communications with other data processing systems or devices. In these examples, communications unit **2710** is a network interface card. Communications unit **2710** may provide communications through the use of either or both physical and wireless communications links.

Input/output unit **2712** allows for input and output of data with other devices that may be connected to data processing system **2700**. For example, input/output unit **2712** may provide a connection for user input through a keyboard, a mouse, and/or some other suitable input device. Further, input/output unit **2712** may send output to a printer. Display **2714** provides a mechanism to display information to a user.

Instructions for the operating system, applications, and/or programs may be located in storage devices **2716**, which are in communication with processor unit **2704** through communications fabric **2702**. In these illustrative examples, the instructions are in a functional form on persistent storage **2708**. These instructions may be loaded into memory **2706** for execution by processor unit **2704**. The processes of the different embodiments may be performed by processor unit **2704** using computer-implemented instructions, which may be located in a memory, such as memory **2706**.

These instructions are referred to as program code, computer usable program code, or computer readable program

code that may be read and executed by a processor in processor unit **2704**. The program code in the different embodiments may be embodied on different physical or computer readable storage media, such as memory **2706** or persistent storage **2708**.

Program code **2718** is located in a functional form on computer readable media **2720** that is selectively removable and may be loaded onto or transferred to data processing system **2700** for execution by processor unit **2704**. Program code **2718** and computer readable media **2720** form computer program product **2722** in these examples. In one example, computer readable media **2720** may be computer readable storage media **2724** or computer readable signal media **2726**. Computer readable storage media **2724** may include, for example, an optical or magnetic disk that is inserted or placed into a drive or other device that is part of persistent storage **2708** for transfer onto a storage device, such as a hard drive, that is part of persistent storage **2708**.

Computer readable storage media **2724** also may take the form of a persistent storage, such as a hard drive, a thumb drive, or a flash memory, that is connected to data processing system **2700**. In some instances, computer readable storage media **2724** may not be removable from data processing system **2700**. In these examples, computer readable storage media **2724** is a physical or tangible storage device used to store program code **2718** rather than a medium that propagates or transmits program code **2718**. Computer readable storage media **2724** is also referred to as a computer readable tangible storage device or a computer readable physical storage device. In other words, computer readable storage media **2724** is a media that can be touched by a person.

Alternatively, program code **2718** may be transferred to data processing system **2700** using computer readable signal media **2726**. Computer readable signal media **2726** may be, for example, a propagated data signal containing program code **2718**. For example, computer readable signal media **2726** may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other suitable type of communications link. In other words, the communications link and/or the connection may be physical or wireless in the illustrative examples.

In some advantageous embodiments, program code **2718** may be downloaded over a network to persistent storage **2708** from another device or data processing system through computer readable signal media **2726** for use within data processing system **2700**. For instance, program code stored in a computer readable storage medium in a server data processing system may be downloaded over a network from the server to data processing system **2700**. The data processing system providing program code **2718** may be a server computer, a client computer, or some other device capable of storing and transmitting program code **2718**.

The different components illustrated for data processing system **2700** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different advantageous embodiments may be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system **2700**. Other components shown in FIG. **27** can be varied from the illustrative examples shown. The different embodiments may be implemented using any hardware device or system capable of running program code. As one example, the data processing system may include organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being. For example, a storage device may be comprised of an organic semiconductor.

In another illustrative example, processor unit **2704** may take the form of a hardware unit that has circuits that are manufactured or configured for a particular use. This type of hardware may perform operations without needing program code to be loaded into a memory from a storage device to be configured to perform the operations.

For example, when processor unit **2704** takes the form of a hardware unit, processor unit **2704** may be a circuit system, an application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device is configured to perform the number of operations. The device may be reconfigured at a later time or may be permanently configured to perform the number of operations. Examples of programmable logic devices include, for example, a programmable logic array, a programmable array logic, a field programmable logic array, a field programmable gate array, and other suitable hardware devices. With this type of implementation, program code **2718** may be omitted because the processes for the different embodiments are implemented in a hardware unit.

In still another illustrative example, processor unit **2704** may be implemented using a combination of processors found in computers and hardware units. Processor unit **2704** may have a number of hardware units and a number of processors that are configured to run program code **2718**. With this depicted example, some of the processes may be implemented in the number of hardware units, while other processes may be implemented in the number of processors.

In another example, a bus system may be used to implement communications fabric **2702** and may be comprised of one or more buses, such as a system bus or an input/output bus. Of course, the bus system may be implemented using any suitable type of architecture that provides for a transfer of data between different components or devices attached to the bus system.

Additionally, a communications unit may include a number of devices that transmit data, receive data, or transmit and receive data. A communications unit may be, for example, a modem or a network adapter, two network adapters, or some combination thereof. Further, a memory may be, for example, memory **2706**, or a cache, such as found in an interface and memory controller hub that may be present in communications fabric **2702**.

Thus, the different advantageous embodiments provide a method and apparatus for identifying a target object in an image. In particular, a method and apparatus for identifying a target object in an image using contextual information identified in the image is provided. In one advantageous embodiment, a group of objects are identified in an image. The group of objects provides a context for identifying a target object in the image. The image is then searched for the target object using the context provided by the group of objects.

In this manner, the different advantageous embodiments provide a system for identifying target objects more rapidly and/or accurately than currently-available systems. Additionally, the amount of computing resources needed to identify target objects in images may be reduced. Further, the time and/or effort spent by an operator identifying which identifications of target objects are false identifications may be reduced.

The description of the different advantageous embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to

the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art.

Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method for identifying a target object comprising at least one of a road and a building from an image taken using synthetic aperture radar (SAR) data, the method comprising:

generating a mask by:

selecting, using the processor, a first threshold and a second threshold of a plurality of thresholds based on a cumulative histogram for the image, wherein the cumulative histogram plots a level of intensity versus a cumulative percentage of pixels in the image;

selecting, using the processor, a percentage using the cumulative histogram, the percentage being the percentage of pixels that are to be included in a process for identifying a set of bright areas and a number of shadow areas;

using an area detector, executed by the processor, to identify the set of bright areas and the number of shadow areas in the image using the plurality of thresholds, including the first threshold and the second threshold;

identifying bright areas by applying the plurality of thresholds, including the first threshold, to the image to identify a number of binary images in which each pixel in a given binary image has a first set of two values, either a first value indicating that a first intensity for that pixel is less than the first threshold or a second value that indicates that a second intensity for that pixel is greater than the first threshold, wherein the bright areas are pixels that are above the first threshold;

identifying number shadow areas by applying the plurality of thresholds, including the second threshold in the plurality of thresholds, to the image to identify a second number of binary images in which each pixel in a given binary image has a second set of two values, either a third value indicating that the first intensity for that pixel is less than the second threshold or a fourth value that indicates that the second intensity for that pixel is greater than the second threshold, wherein the shadow areas are pixels that are below the second threshold, and wherein the first threshold is greater than the second threshold;

wherein generating the mask is performed by processing the bright areas and the shadow areas to identify which objects in the image may be the target object;

searching, by the processor and using the mask, for the target object within the number of regions.

2. The method of claim **1**, wherein searching for the target object in the image further comprises:

responsive to identifying a particular object in the image as the target object, determining whether the particular object is the target object based on a location of the particular object to a group of objects.

3. The method of claim **2**, wherein searching for the target further comprises:

searching for the target object in the image using a context provided by the group of objects with a number of agents, wherein an agent in the number of agents is configured to search for the target object within a window for the agent.

4. The method of claim **3**, wherein searching for the target object in the image using the context provided by the group of objects comprises:

searching for the target object in the image in a number of regions in the image using a particle-swarm optimization process, wherein the number of regions is identified using the context provided by the group of objects.

5. The method of claim **1**, wherein generating the mask further comprises:

identifying a set of lines in the image and processing the set of lines along with the bright areas and the shadow areas.

6. The method of claim **1** wherein generating the mask further comprises:

prior to selecting the first and second thresholds, processing the SAR data to reduce noise present in the image.

7. An apparatus for identifying a target object comprising at least one of a road and a building from an image taken using synthetic aperture radar (SAR) data, the apparatus comprising:

a processor configured to generate a mask, the processor being specifically configured to:

select, using the processor, a first threshold and a second threshold of a plurality of thresholds based on a cumulative histogram for the image, wherein the cumulative histogram plots a level of intensity versus a cumulative percentage of pixels in the image;

select, using the processor, a percentage using the cumulative histogram, the percentage being the percentage of pixels that are to be included in a process for identifying a set of bright areas and a number of shadow areas;

use an area detector, executed by the processor, to identify the set of bright areas and the number of shadow areas in the image using the plurality of thresholds, including the first threshold and the second threshold;

identify bright areas by applying the plurality of thresholds, including the first threshold, to the image to identify a number of binary images in which each pixel in a given binary image has a first set of two values, either a first value indicating that a first intensity for that pixel is less than the first threshold or a second value that indicates that a second intensity for that pixel is greater than the first threshold, wherein the bright areas are pixels that are above the first threshold;

identify number shadow areas by applying the plurality of thresholds, including the second threshold in the plurality of thresholds, to the image to identify a second number of binary images in which each pixel in a given binary image has a second set of two values, either a third value indicating that the first intensity for that pixel is less than the second threshold or a fourth value that indicates that the second intensity for that pixel is greater than the second threshold, wherein the shadow areas are pixels that are below the second threshold, and wherein the first threshold is greater than the second threshold;

wherein generating the mask is performed by processing the bright areas and the shadow areas to identify which objects in the image may be the target object;

the processor further configured to search, using the mask, for the target object within the number of regions.

8. The method of claim 1 further comprising:

prior to identifying the group of objects, preprocessing the image to reduce noise in the image.

9. The method of claim 1, wherein the context further includes additional information obtained from sources other than the image.

10. The method of claim 9, wherein the additional information is selected from the group consisting of: intelligence information, mission details, and weather data.

11. The method of claim 1, wherein the number of masks is selected from the group consisting of a building mask, a vegetation mask, and a road mask.

12. The method of claim 11, wherein the number of masks comprises all of the building mask, the vegetation mask, and the road mask.

13. The method of claim 1, wherein the plurality of thresholds is a plurality of thresholds, and wherein other thresholds within the plurality of thresholds are selected by substantially equally dividing an interval between the first threshold and a highest level of intensity in the image by a total of the plurality of thresholds.

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